Pacific Island Network
Vital Signs Monitoring Plan

Appendix E: Topical Working Group Report – Vegetation & Flora

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Pacific Island Network (PACN)

Territory of Guam
War in the Pacific National Historical Park (WAPA)

Commonwealth of the Northern Mariana Islands
American Memorial Park, Saipan (AMME)

Territory of American Samoa
National Park of American Samoa (NPSA)

State of Hawaii
USS Arizona Memorial, Oahu (USAR)
Kalaupapa National Historical Park, Molokai (KALA)
Haleakala National Park, Maui (HALE)
Ala Kahakai National Historic Trail, Hawaii (ALKA)
Puukohola Heiau National Historic Site, Hawaii (PUHE)
Kaloko-Honokohau National Historical Park, Hawaii (KAHO)
Puuhonua o Honaunau National Historical Park, Hawaii (PUHO)
Hawaii Volcanoes National Park, Hawaii (HAVO)

http://science.nature.nps.gov/im/units/pacn/monitoring/plan/

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Table of Contents

List of Figures

List of Tables

Executive Summary

Ten of the 11 National Parks in the Pacific Island network have vegetation that requires monitoring. The larger parks (HAVO, HALE, KALA, NPSA) support a wide diversity of native, near-native, and invaded plant communities, ranging from shoreline to alpine zone and from very wet to very dry climate regimes. Vegetation types include strand, grasslands, shrublands, woodlands, forests, and bogs. Smaller Historical Parks contain remnants of native communities within a broader historical or cultural landscape, but are often highly invaded by alien plant species. Plant species introduced by indigenous people during settlement of the islands are currently a component of many of the parks. Alien vegetation has encroached on native communities and cultural landscapes of all parks.

A monitoring system provides resource managers with information essential to managing vegetation. Effective monitoring is an early warning system for detecting and eradicating incipient invasive species and produces data on population and community status and trends for developing management strategies. Monitoring addresses changes in the populations of native, alien, culturally significant, and rare plant species. Monitoring also detects changes in plant communities over time and across landscapes. Community monitoring in the parks is typically concerned with successional patterns after fire, alien ungulate disturbance, invasion of alien species, or recovery after management. Monitoring provides information on effects of disturbances, such as fires, hurricanes, subsistence agriculture, and introduced ungulates; provides feedback about alien species, restoration programs, and visitor impacts; helps to assess the effects of habitat fragmentation; and is a means of measuring progress meeting reporting requirements.

This document is intended to be an overview of the current knowledge regarding terrestrial vegetation resources and current vegetation monitoring in all Pacific Island National Parks. It also highlights gaps in our current knowledge, which in some parks are considerable. A summary of each park follows, including geographic setting, legal mandate, existing vegetation resources, critical vegetation resources, stressors, monitoring needs, and current monitoring efforts.

ALKA. The vegetation resources of the recently-designated, 280-km-long (175-mile) Alakahakai Trail have not been inventoried.

AMME. American Memorial Park includes 53 ha (133 a) on the coast of Saipan in the Northern Marianas. The park was established as a memorial honoring the sacrifices made in the Mariana Islands during WWII. AMME contains a memorial structure surrounded by a mowed recreational area. Most of the park is covered by alien vegetation except for persistent strand vegetation and a wetland containing native mangroves (*Bruguiera gymnorrhiza*) and other indigenous plants. The wetland, which provides habitat for two endangered bird species and a rare tree snail, is the most significant vegetation resource of AMME. The most important stressors are human uses, including trampling, illegal harvesting of vegetation, and rubbish dumping. Encroachment from adjacent development may be altering hydrology of the wetland. The most important monitoring need is documentation of changes in the wetland community.

Baseline transects were established in the wetland in the late 1980s, and additional vegetation studies have recently been completed.

HALE. Haleakala National Park includes approximately 12,000 ha (30,000 a) on the island of Maui, in the Hawaiian Islands. It extends from the shoreline to over 3,000 m (10,000 ft) elevation at the summit of Haleakala Volcano. The park was established to protect and provide access to geological resources, but it also contains significant biological resources. HALE vegetation resources include coastal strand, highly disturbed lowland wet and mesic forest, intact lowland and montane rain forests and cloud forests, montane bogs, subalpine grasslands and shrublands, montane dry forest remnants, and alpine cinder fields. Recovering alpine-aeolian cinderland, subalpine grassland/shrubland, montane bogs, cloud forest, rain forest, and dry to mesic leeward shrublands and forests are all notable for high native species diversity. The protected rain forests of Kipahulu Valley, a research area and scientific reserve, are particularly important. Subalpine lakes and riparian habitat of perennial streams are valuable resources.

The park supports at least 15 threatened and endangered plant species, a few candidate endangered species, approximately 14 species of concern, and 30 rare plant species. Additional species within these categories have been extirpated from HALE. The main stressors here are those found throughout the Hawaiian Islands: wildfire; disease; visitor impacts in the alpine zone and riparian areas; loss of key species; established alien species, including highly invasive plants (e.g. *Miconia calvescens*), feral ungulates, rats, ants, yellowjacket wasps, mosquitoes; and potential new introductions.HALE managers have identified monitoring needs as rare plant population monitoring; continued treatment effectiveness monitoring in areas of management activity; recovery of significant plant communities; and alien plant distribution monitoring, including monitoring for incipient invaders. A substantial body of vegetation monitoring has been conducted in HALE, with the intent of establishing baselines for long-term monitoring. Vegetation maps were prepared for three portions of the park with different methods and scales in the 1980s. Much of the rare plant flora has been inventoried, and monitoring of the threatened Haleakala silversword (*Argyroxiphium sandwicensis* subsp. *macrocephalum*) is a long-term, systematic program. However, monitoring projects have only been carried out for short periods in the dry forest remnants, montane bogs, and montane rain forests.

Alien plant monitoring methods emphasize checklists, vegetation mapping, distribution and frequency monitoring along transects, treatment monitoring and research into control techniques, alien plant species role within monitored vegetation communities, and impacts of individual species. HALE resource managers have been highly successful in feral goat and pig removal. Vegetation recovery monitoring was established in sub alpine grasslands, leeward shrublands, montane bogs, montane rain forests, and in Haleakala Crater. Some vegetation recovery projects focused on exclosures predating ungulate removal; others were along long transects. Studies of alien plants and vegetation recovery after ungulate removal could serve as long-term monitoring. Other studies in rain forests, grasslands, bogs, leeward shrublands, and Haleakala Crater may serve as baseline data sets for future monitoring.

HAVO. Hawaii Volcanoes National Park is an approximately 133,000 ha (333,000-acre) area on the island of Hawaii, which was established in 1916 to protect volcanic scenery. In 2003, 46,000 ha (116,000 a) of the adjacent Kahuku Ranch were acquired as an addition to HAVO (then 86,800 ha). The park extends from shoreline to 4,170 m (13,679 ft) elevation. HAVO vegetation includes coastal strand , remnant lowland wet and dry forests, dry open woodland, early succession vegetation on lava flows, montane rain forest, montane mesic forest, montane dry forest, sub alpine forest and shrubland, and a sparsely vegetated alpine zone. The most significant vegetation resources are relict dry forests; early succession lava flows and kipuka; beach strand communities and associated anchialine ponds; lowland ecosystems proposed for restoration; upper montane, subalpine and alpine communities of Mauna Loa; and the diverse mesic and rain forests of both Mauna Loa and Kilauea. The vegetation resources of Kahuku have not been evaluated, but a vascular plant inventory of the addition is scheduled for 2005.

Excluding Kahuku, HAVO contains 22 threatened and endangered plant species, 5 candidate endangered species, 22 species of concern, and at least 40 rare plant species; these numbers include several extirpated and extinct species. Many native plant species and communities are culturally significant for traditional gathering. The main stressors are invasive alien plants; feral ungulates; wildfire; lava flows; rats; yellowjacket wasps; mosquitoes; ants; disease; adjacent land use; park development; visitor impacts; loss of pollinators; changes in nutrient, soil water, and fire regimes; and small population size of endemic organisms leading to species loss. The most important monitoring needs are for rare plant populations; treatment effectiveness in areas of management activity; recovery of significant plant communities; alien plant distributions, including those of incipient invaders; impacts of cultural collecting; fire effects; early succession on lava flows; and long-term changes in rain forests, diverse mesic forests, and upper montane to alpine ecosystems.

A substantial body of vegetation monitoring has been conducted at HAVO, although not in a systematic park-wide program. Vegetation mapping occurred in the 1970s, 1980s, and 1990s using different classification schemes. Systematic rare plant surveys have been conducted in key park communities, including lowland dry forest, montane mesic forest, montane rain forest, and montane and sub alpine dry forest and woodland. Selected individual species have been monitored for short periods of time. Monitoring is associated with out-plantings of nearly 60 rare plant species. Inventory work has been detailed enough to serve as a baseline for future monitoring efforts, and the distributions of over 80 species have been mapped for future monitoring. Alien plant frequency transects have been established along the Mauna Loa Strip, and in the Olaa Forest, the East Rift forests, Kipuka Puaulu and Kipuka Ki, Thurston Special Ecological Area, and Kipuka Kahalii. Faya tree (*Morella faya*) spread and dieback has been monitored throughout its range in the park and plant succession is being monitored in faya-invaded communities. Monitoring has been established to detect recovery of vegetation after feral ungulate removal in the coastal lowlands, East Rift forests, Olaa Tract, and Mauna Loa Strip. Repeated alien plant inventories help to qualitatively monitor vegetation changes. As fire is a major stressor at HAVO, plant succession following fire has been monitored in the coastal lowlands, dry ohia lehua (*Metrosideros polymorpha*) woodlands, montane seasonal forest and shrublands, and rain forest, as well as in nine prescribed burns areas. Experimental restoration projects are underway in coastal lowlands, dry ohia woodlands, koa (*Acacia koa*) forest, and abandoned pastures and vegetation response is monitored at these study sites. Many past and current alien plant, fire effects, and recovery-after-ungulate-removal studies could be treated as long-term monitoring.

KAHO. Kaloko-Honokohau National Historical Park is a coastal park of approximately 470 ha (1,160a) that was established to preserve Native Hawaiian culture, with the pre-Western-contact era of Hawaiian inhabitation as the target for the historical landscape. While remnants of the coastal strand persist and significant wetland communities remain, most of the park vegetation has been altered by invasive plant species. Two important invasive plants are kiawe (*Prosopis pallida*) in shoreline and wetland areas and fountain grass (*Pennisetum setaceum*) on previously bare lava flows. The most critical vegetation resources are wetlands surrounding two large fishponds, coastal strand, and wetland vegetation around anchialine pools. The park supports a large population of the species of concern pua pilo (C*apparis sandwichiana*) and smaller numbers of two other rare plant species. Main stressors on vegetation are alien plant species, shoreline erosion, ungulates, rats, ants, loss of biodiversity, development of coastal lands near the park, and visitor impacts to natural resources. Potential stressors include sea level rise due to global warming, expansion of Honokohau Harbor, development of upslope lands, increased visitation, and incipient invasives. The most important monitoring needs are wetland communities, native tree and shrub populations, effectiveness of native plant re-introductions in alien plant removal areas, and alien plant treatment effectiveness. KAHO vegetation was mapped in the 1980s. Baseline studies on three rare plant species could be revisited. Monitoring of alien plant species consists of treatment effectiveness records. Baseline inventory data on alien and native plant distributions could be developed into a long-term monitoring effort.

KALA. Kalaupapa National Historical Park encompasses approximately 4,365 ha (10,778 a) on the island of Molokai, where the park was established to preserve the cultural landscape of a Hansen's disease colony, along with scenic values of the area. KALA has coastal strand, loulu lelo (*Pritchardia hillebrandii*) coastal forest, remnant lowland mesic forest, native vegetation on cliff faces, and lowland rain forest. Montane rain forests and wet cliff vegetation covers most of the Puu Alii Natural Area Reserve, within the authorized boundaries of KALA. Critical vegetation resources are the upper-elevation rain forest of Waikolu Valley and Puu Alii, diverse dry forest in Kauhako Crater, and coastal strand communities. The park supports or formerly supported 27 plant species listed as endangered, 2 threatened plant species, 5 candidates for endangered status, and at least 22 species of concern. Several endangered plant species have been reported from Kalaupapa Peninsula, and others may be on unsurveyed cliffs in or near the park. Awiwi (*Centaurium sebaeoides*), an endangered annual herb, and the threatened *Tetramolopium rockii* var. *rockii* are both strand community components. Offshore islets support unusual relict vegetation, as well as the endangered plant species dwarf naupaka (*Scaevola coriacea*) and pua ala (*Brighamia rockii*). Many endangered species and species of concern are known from rain forests of Puu Alii NAR, some of which have not been observed for many years.

The main stressors at KALA are invasive alien plants and animals (ungulates, rats, mosquitoes, ants); disease; loss of biodiversity; and human impacts on offshore islands. Potential stressors include incipient invaders and the alteration of disturbance and succession regimes. The chief monitoring needs are community recovery after feral ungulate removal; *Pritchardia* coastal forest restoration; rare plant population monitoring; vegetation mapping at a scale showing native vegetation fragments and patch size; and rain forest boundary mapping. Vegetation has been mapped in the coastal strand and in portions of the park uplands. Monitoring programs have been designed for four endangered plant species and for rare plants of Kauhako Crater. KALA does not have specific monitoring of alien plants but restoration projects focused on Kauhako Crater and the coastal strand have included alien plant monitoring components. These projects may also contribute to assessment of vegetation recovery after ungulate removal.

Kauhako Crater monitoring, coastal plant inventories, offshore islet surveys, and vegetation data from upper-elevation Forest Bird Survey transects, could be developed further for a long-term monitoring program.

NPSA. The National Park of American Samoa includes 3,227 ha (7,970 a) of land and 1,012 ha (2,550 a) of adjacent ocean. The park's boundary extends offshore 0.4 km (0.25 mi) to a water depth of 30 m (100 ft). NPSA is comprised of four units on four islands of American Samoa: Tutuila, Tau, Olosega, and Ofu. In 2002, Congress approved an expansion of the park on Olosega and Ofu Islands. The legislation establishing the park recognized the importance of the Samoan tropical forests as among the last remaining undisturbed paleotropical rain forests and as habitat of Pacific flying foxes. NPSA units include vegetation from coastal strand and littoral (or coastal) forest to maota (*Dysoxylum* spp.) lowland rain forest, montane rain forest, and fern-dominated summit scrub. Apart from the littoral plants at the shore, rain and cloud forests are thought to have been the original vegetation cover of all the islands of Samoa. The current vegetation of American Samoa is the result of thousands of years of human disturbance from agriculture and logging. Montane rain forest and summit scrub is most vulnerable on Tutuila, and the lowland maota mamala (*Dysoxylum samoense*) rain forest is a critical resource of Tau. All other native vegetation types in the park should also be considered important, as they are unique among NPS units. Rare plant species need to be identified and protected; no Samoan plants are currently listed as endangered, but several are considered species of concern. Native fruit-bearing tree species are important as food sources for rare fruit bats (*Pteropus samoensis* and *P. tonganus*) and uncommon Many-colored Fruit Doves (*Ptilinopus perousii*). Plants of ethnobotanical importance are also potential monitoring subjects.

The important stressors on vegetation are disease; invasive species (feral pigs, rats, ants, plants, etc); and expansion of subsistence agriculture into forests. Potential stressors are incipient invaders, climate change, hurricanes, incompatible tourism-related development on adjacent lands, and human population growth. The most important monitoring needs at NPSA are rain forest ecosystem health; expansion of subsistence farming and effects of human disturbance; ungulate impacts on native vegetation; alien plant distribution monitoring; effectiveness of weed treatment and ungulate removal; and, once they are defined, population trends of rare plants. Mapping efforts at NPSA include a 1981 coastal management atlas, a vegetation survey and forest inventory, generalized vegetation types in the 1994 General Management Plan, vegetation type maps for Tau and Tutuila, and a land delineation effort in 2002 that recognized management and land use categories. Park-wide rare and alien plant monitoring has not been initiated, but recent plant inventories in three units have provided baseline information for future monitoring. Long-term vegetation plots have recently been established in several vegetation types of the Tutuila unit.

PUHE. Puukohola Heiau National Historical Site is a 35-ha (86-a) coastal park on the island of Hawaii that was established to protect Hawaiian culture and historical sites. The era of Hawaiian inhabitation, specifically the period of temple construction for Puukohola Heiau (ca. 1790), is the target historical period. Natural vegetation has been largely replaced by alien vegetation, and many native species exist in the park only as plantings by park staff. PUHE has the most altered vegetation of the five Hawaii Island parks. Critical vegetation resources are concentrated in the strand and small wetland community. Experimental areas where pili grass (*Heteropogon contortus*) is being restored are important examples for future restoration efforts. A population of the rare pololei fern (*Ophioglossum polyphyllum*) persists at one site in the park. The primary threats to the park's resources are invasive alien plant species, particularly kiawe , puncture vine (*Tribulus terrestris*), and fountain grass; alien trees, shrubs, and vines that may damage cultural resources; pickleweed (*Batis maritima*) recently removed from the coastal wetland; fire; erosion; and in-park development. Potential stressors are development of a liquid-fuel storage facility adjacent to the park; fuel spills and increased visitation from adjacent Kawaihae Harbor; and off-road bikes or motorcycles using the coral flats and stream banks. Perceived information needs are treatment effectiveness monitoring in pili restoration areas; population monitoring of the rare pololei fern; and monitoring of re-introduced native plants and restored communities. A vegetation map has not been prepared for PUHE. Little alien plant monitoring has been done but a 30-year old study of roadside alien plants could be replicated in a portion of the park.

PUHO. Puuhonua o Honaunau National Historical Park is comprised of 74 ha (182 a) on the coast of Hawaii Island; it was established to protect Hawaiian culture and historical sites. The Hawaiian era prior to Western contact in 1778 is the target historical period. Most natural vegetation has been replaced by alien species, but many Polynesian and indigenous species have been planted by park staff near the Visitor Center. Critical vegetation resources are coastal strand and marsh surrounding anchialine pools; these support primarily native vegetation. Other native plants are found scattered in vegetation dominated by alien plants. One species of concern and several uncommon lowland plant species are known from the park. Endangered loulu palms (*Pritchardia affinis*) have been planted near the Visitor Center. The detached upland garden has out-plantings of several additional endangered plant species. Stressors include erosion of coastal areas, particularly with rising sea level; encroaching development; and invasive alien plants, including both those already established (e.g. koa haole, *Leucaena leucocephala* and opiuma, *Pithecellobium dulce*) and invaders not yet well-established in the park (e.g. ivy gourd or *Coccinia grandis*). Perceived monitoring needs are: population monitoring of selected native and Polynesian plant species; community-level monitoring of coastal strand and wetland vegetation; effects of alien plant treatments, and efficacy of native plant re-introductions. A vegetation map was prepared in the 1980s and recently updated. PUHO has a long history of alien plant control, and park monitoring included tracking treatment effectiveness. A pilot monitoring project to determine frequency and abundance of native plants and invasive alien plant species in the mid 1990s could be repeated. No other vegetation monitoring programs are ongoing.

USAR. The USS Arizona Memorial is a 4-ha (10-a) site in Pearl Harbor, island of Oahu, Hawaii. There are no terrestrial vegetation resources in this park unit. The Visitor Center is built on land created from fill and is maintained within an armored shoreline.

WAPA. War in the Pacific National Historical Park is comprised of seven units with a total area of approximately 400 ha (1,000 a) in the Territory of Guam, Mariana Islands. The enabling legislation states that the campaigns of the Pacific theater of WWII are to be commemorated and the natural and scenic values of Guam are to be conserved. WAPA supports coastal vegetation, limestone forest, savanna, and ravine or riverine forest, as well as disturbed areas of secondary vegetation. Several small coastal wetlands occur in or near park units, and there are stream-associated wetlands and springs within the inland units. The Apaca Point area of the Agat Unit has been designated as part of the Namo River floodplain wetland by the Guam Coastal Management Program. The significance of this wetland is reocgnized by the United Nations

Protected Area Program. Critical vegetation resources are limestone forest remnants, riverine forests, and savanna vegetation recovering from fire. The Asan Inland and Asan Beach units comprise an entire sub-watershed. Stressors to WAPA vegetation are adjacent development; invasive ungulates, particularlyferal pigs (*Sus scrofa scrofa*) and Philippine deer (*Cervus mariannus*); alien plants; wildfire and subsequent erosion, particularly in savanna vegetation; the Brown Tree Snake (*Boiga irregularis*) that has decimated native bird pollinators and seed dispersers; and severe typhoons that repeatedly disturb vegetation cover, particularly in limestone forest. Monitoring needs include studies of fire effects and erosion in savanna vegetation; impacts of feral ungulates and alien plant species; and changes in limestone forest composition and cover. WAPA vegetation has not been specifically mapped, but a broad-scale vegetation map of Guam includes park units. The flora of WAPA was inventoried for the first time in 2004 (Yoshioka in prep.), and more than 350 plant species were observed within the park. One park unit provides habitat for a species of concern. Other plants recognized as rare by the Government of Guam may exist in unsurveyed sections, but WAPA probably does not support Guam's one Federally-listed endangered plant species. No long-term vegetation monitoring has been carried out in WAPA.

Introduction

General Definition of Topic Area

Vegetation and flora monitoring includes the study of alien and native plant species populations and plant communities. Population monitoring addresses changes in populations of incipient invasive species and alien plants established in the parks, Polynesian introductions, harvested species, other key native species, and rare species including those listed as Threatened or Endangered. Community monitoring includes quantitative monitoring and vegetation mapping of the spatial distribution of plant communities. Community monitoring typically addresses successional patterns following fire, ungulate disturbance, or invasion of alien plants; recovery after alien species control; and ecological restoration efforts. Community monitoring and vegetation mapping may be used to analyze vegetation change from the perspective of the vegetation landscape (including landscape metrics such as fragmentation and patch size).

Monitoring Objectives

A monitoring program will provide data for the following objectives:

- An early warning system for managers about newly invasive plant species, changes in established alien plant populations and plant communities, and loss of rare or key native species. This knowledge will help to develop effective control and mitigation measures.
- Information about status and trends in plant populations and communities to better understand them and develop strategies for alien species control and ecological restoration programs.
- Feedback about effects of disturbance, alien species control, ecological restoration, and rare species management programs to help managers manage adaptively.
- Assessment of the effects of habitat fragmentation, development of strategies for conservation partnerships, and evaluation of landscape level restoration attempts.

- Progress measurement and reporting requirements of the performance management system, Endangered Species Act, and other Congressional mandates.

ISSUES IN CONTEXT

The monitoring program will operate within an adaptive management feedback loop to help establish and evaluate alien species control, ecological restoration, and rare species recovery programs. Some monitoring activities will provide long-term monitoring independent of specific management treatments, but most monitoring will be tied to management treatments.

Operational Mandates, Legislation, and Policy

PARK ENABLING LEGISLATION

HALE and HAVO legislation do not have specific language regarding vegetation. For PUHE, the enabling legislation names Kamehameha the Great and John Young and specifies the period of Kamehameha's ascendancy to power (ca. 1790) as the historical time that the Park commemorates. PUHO and KAHO were established to protect Hawaiian cultural and historical sites, and the era of Hawaiian inhabitation is the model for the historical landscape. The natural resources of KALA are not addressed in the establishment act, except as "scenic resources." ALKA legislation does not mention vegetation or natural resources of the 280-km (175-mile) historic trail. The enabling legislation of WAPA states that the campaigns of the Pacific theater of World War II are to be commemorated, and the natural and scenic values of Guam are to be conserved. Likewise, AMME was established on Saipan to honor those who died in the WWII Mariana Islands campaign, and no vegetation management is specified. The act establishing NPSA recognized the importance of the park's tropical vegetation as one of the last remaining undisturbed paleotropical forests and as habitat of Pacific flying foxes (Pteropus spp.).

ENDANGERED SPECIES ACT

Parks with endangered species resources are expected to conserve their habitat under the Endangered Species Act of 1973. Recovery plans for individual species or groups address the actions needed to recover endangered species. Critical habitat designations for endangered plants of the Hawaiian Islands include areas within several National Parks.

All the National Parks of the Hawaiian Islands, except USAR and ALKA, support endangered plants or species of concern. USAR has no terrestrial plant resources and ALKA has not been surveyed for rare plants. PUHE and PUHO currently contain only planted individuals of endangered species, but several endangered plants may have been among the original coastal vegetation of the parks. The three Western Pacific parks do not contain federally listed endangered plants. WAPA has only recently been surveyed. One species of concern (*Tinospora homosepala*) was confirmed in a coastal unit (Yoshioka, in prep.); WAPA probably does not support the one federally listed endangered plant species of Guam (*Serianthes nelsoni*) (USFWS 1994). Endangered plant species have not been designated for American Samoa, although five Samoan plants are listed as species of concern.

NPS MANAGEMENT POLICIES

Monitoring programs will provide parks with data to help manage vegetation resources. Whenever possible, natural, non-intrusive, processes will be relied upon to maintain native plants and communities. Monitoring data are needed to determine the efficacy of this approach. More hands-on management is often required in island ecosystems, due to invasive species problems.

NPS management policies include provisions for preserving native plant populations and communities of parks and restoring those extirpated by human actions (NPS 2001). Seeds, cuttings, or transplants may be used for reintroduction. If control is feasible, alien or exotic plant species are to be managed where they interfere with natural processes; impact the perpetuation of native species; disrupt the genetic integrity of natives; damage cultural resources or landscapes; or pose a hazard to public health and safety. Parks will maintain and restore the diversity of genotypes or genetic diversity appropriate to the park unit and needed for long-term fitness of species. The parks will actively manage threatened and endangered plant species, as well as "species of concern," through inventory, survey, monitoring, and restoring habitat. Managers will attempt to recover endangered species native to the park units by manipulating target rare plant populations through out-planting, seed broadcast or other recovery techniques. Guidelines for revegetation in disturbed areas of National Parks were given in the 1993 Western Regional Directive WR-94 (NPS 1993). The primary goal of park revegetation is "...the preservation of native plant species, community types, and ecosystem processes." Culturally significant vegetation may also be preserved by revegetation, particularly in the Historical Parks.

LOCAL CONTROLS AND REGULATIONS

The State of Hawaii has legislation that allows for the listing of endangered plant species at the State level. All Hawaiian plants recognized on the Federal endangered species list have been listed as threatened or endangered by the State (State of Hawaii 1998). The State of Hawaii has noxious weed regulations that recognize some alien plant species as particularly invasive and permits State agencies to cooperate with landowners and provide herbicides, equipment, and personnel to control infestations (State of Hawaii 1992). However, compliance with the regulations is not evenly enforced, and many of the worst alien plant species are not listed as noxious weeds because they are considered too widespread to control. HAVO has developed protocols for rare plant seed collection and propagation, greenhouse sanitation procedures, and out-planting strategies to prevent the unintentional spread of alien weed seeds and invertebrate pests (Tunison 2000). Other non-NPS groups have developed standard protocols for propagating and out-planting rare plant species in natural areas (Hawaii Restoration Group; Hawaii Pacific Endangered Plant Recovery Coordinating Committee).

Geographic Context

GEOGRAPHY

All the network parks are found on tropical islands in the Pacific Ocean. Eight of the parks are in the Hawaiian Islands in the Central Pacific between 19 and 22 degrees North latitude. HAVO, KAHO, PUHE, PUHO, and the recently designated ALKA are on the island of Hawaii, the youngest of the main Hawaiian Islands at the southern and eastern end of the archipelago. HAVO is located on the southeast slope of Hawaii Island, where it extends from sea level to the summits of Kilauea and Mauna Loa Volcanoes. The newly designated Kahuku unit of HAVO is positioned on southern Mauna Loa and extends down both the eastern and western flanks of the volcano. PUHE, KAHO, and PUHO are coastal parks on the western side of the island; KAHO is centrally located with PUHE to the north and PUHO to the south. HALE is on Maui, the second youngest Hawaiian Island; HALE extends from sea level to the summit of East Maui. KALA is on a peninsula projecting from the north shore of Molokai, centrally located in the main Hawaiian Islands. USAR is within Pearl Harbor on southern or leeward Oahu. Two PACN parks are situated in the western Pacific Ocean between 13 and 15 degrees north latitude in Micronesia. WAPA is on the western side of the island of Guam and AMME is on the west coast of Saipan, one of the Northern Mariana Islands. NPSA is located in Polynesia on islands of American Samoa (14 degrees S). One unit of NPSA is on the island of Tutuila; three others are on Tau, Ofu, and Olosega of the Manua Island group 96 km (60 miles) east of Tutuila.

GEOLOGY

The parks of the Western Pacific (WAPA, AMME) are on islands (Guam and Saipan) with long-extinct volcanoes. These islands have complicated geologic origins involving both volcanism and subduction of the Marianas Trench. The northern half of Guam and portions of Saipan have limestone substrates elevated above a weathered volcanic base. WAPA units are on the volcanic substrates of the southern half of Guam, but several units include elevated limestone caps or limestone ridges.

The islands of American Samoa and Hawaii are oceanic volcanic islands arising from hotspots. The oldest of the Samoan Islands are dated at more than two million years, but there was volcanic activity between Tau and Olosega approximately 150 years ago (Whistler 1994). In Hawaii, HALE protects the summit of the inactive Haleakala Volcano and its impressive crater, which is the result of stream erosion, the merging of Kaupo and Keanae Valleys, and subsequent volcanic activity. KALA encompasses the Kalaupapa peninsula, formed on the north shore of Molokai during the Pleistocene (MacDonald and Abbott 1970). The volcanoes of both Molokai and Oahu are extinct.

The five parks on Hawaii Island are on active or dormant volcanoes. A significant portion of HAVO is covered with recent lava flows that are sparsely vegetated. HAVO also contains the rift zones and summit calderas of both Mauna Loa and Kilauea Volcanoes, two of the most active volcanoes on earth. PUHO is on prehistoric pahoehoe flows of Mauna Loa, and PUHE substrates are old weathered soils of Kohala Volcano. All substrates of KAHO are flows from Hualalai Volcano less than 10,000 years old, including one sparsely-vegetated lava flow dated at 1,000-3,000 years (Moore *et al.*1987).

ELEVATION GRADIENTS

Among the Hawaiian parks, HAVO and HALE have the greatest elevational range, extending from sea level to the summits of tall volcanoes >3,000 m (>10,000 ft) in elevation. KALA has an elevational range from sea level to almost 1,220 m (4,000 ft) elevation. The three parks of leeward Hawaii Island are coastal parks and extend upslope to an elevation no more than 100 m. ALKA is also in the coastal lowlands of western and southern Hawaii Island.

Among the three Western Pacific parks, AMME is restricted to coastal lowlands on the western shore of Saipan. WAPA includes both coastal units and inland sites on the slopes of Mt. Alifan and Mt. Tenjo; one unit extends to above 305 m (1,000 ft) elevation. NPSA is composed of four units; Ofu and Olosega are largely coastal but the Tutuila and Tau units range from sea level to 491 m (1,610 ft) and 966 m (3,170 ft) elevation, respectively.

RAINFALL AND CLIMATE

The largest two Hawaiian parks, HAVO and HALE, include within their boundaries several climatic zones with a range of rainfall regimes. HAVO contains two of the four rainfall minima of Hawaii Island, the Kau Desert with mean annual rainfall <750 mm and the interior lands of Mauna Loa with <500 mm annually. The highest mean annual rainfall within the park is found in Olaa Tract, a rain forest with >4,000 mm per year (Giambelluca *et al*. 1986). In general, the eastern windward portion of HAVO has high rainfall, which diminishes upslope, particularly above the trade wind inversion layer near 1,830 m (6,000 ft) elevation. The upper elevations of the park are moist to very dry, and the summit of Mauna Loa receives on average <500 mm precipitation. The leeward, western portions of HAVO are in rain shadows of Mauna Loa and Kilauea summit, and are typically dry.

HALE also has a range of climates, as it extends from sea level on the windward, eastern slope of Haleakala to the summit of East Maui. The park also includes lands in the leeward rain shadow of Haleakala, down to 1,220 m (4,000 ft) elevation. Annual precipitation in the park varies from 1,250 mm in the Crater, southern slope, and Kaupo Gap, to >6,000 mm on the upper northeastern slopes of Haleakala. KALA, on the north shore of Molokai receives 1,000 mm of precipitation annually at sea level and >3,000 mm at the upper elevations of Waikolu Valley (Giambelluca *et al*. 1986). USAR on Oahu is located within Pearl Harbor on the dry leeward side of the island in an area than has on average 600 mm rainfall per year.

The other four Hawaii Island parks are in relatively low rainfall areas with constant warm temperatures and pronounced daily wind patterns of land and sea breezes (Blumenstock and Price 1967). KAHO has a mean annual rainfall of approximately 600 mm and a seasonal climate with higher rainfall during summer months (Canfield 1990a). The climate of PUHO is similar to that of KAHO, with mean annual precipitation of 659 mm. PUHE is located within one of the four rainfall minima of the island of Hawaii and receives <250 mm of rain annually (Giambelluca *et al*. 1986).

The climate of Guam and the Northern Marianas (CNMI), including Saipan, is warm, wet, and tropical. Temperature varies between 70° and 90° F. Relative humidity is high, often exceeding 80% and seldom falling below 50%. The rainfall pattern is strongly seasonal with a wet season from July to November and a pronounced dry season from December to June. Average annual rainfall of the Marianas is 2,160 mm (85 in) (Baker 1951), and on Guam the annual mean is 2,175 mm (Mueller-Dombois and Fosberg 1998). Typhoons are yearly events, which occur during the monsoonal wet season. Trade winds blow from the northeast, but easterly and southeasterly winds prevail during several months in the spring (Baker 1951). Because Guam and the Marianas are relatively low islands, there is no pronounced rain shadow effect, and leeward shores are not drier than those of the windward sides (Mueller-Dombois and Fosberg 1998).

NPSA has a warm tropical climate with little seasonal variation in temperature. Rainfall is high in the four units of the park. On Tutuila, annual rainfall at the airport averages 3,200 mm (126 in.), and may be even higher on the upper mountain slopes within the park. Rainfall is seasonal with greater monthly means from October to May and a dry season from June to September. Hurricanes are occasional but not annual events (Whistler 1994). Tau Island unit is only 96 km (60 miles) east of Tutuila and shares its warm and wet tropical climate. Tau average rainfall is more than 2,500 mm (98 in.) per year and is highest in December. The dry season is June to September, and droughts sometimes occur on the island (Whistler 1992).

NATURAL AND EXISTING VEGETATION

Among the Hawaii parks, the two largest show the greatest diversity of vegetation and the highest proportion of natural vegetation. HAVO includes coastal strand vegetation, remnant lowland wet and dry forest, dry open woodlands, early successional vegetation on lava flows, montane rain forest, montane mesic forest, montane dry forest, sub alpine forest and shrublands, and a sparsely vegetated alpine zone (Doty and Mueller-Dombois 1966). HALE has coastal vegetation, highly disturbed lowland rain forest and mesic forest, intact lowland and montane rain forest, montane cloud forest, montane bogs, sub alpine grasslands and shrublands, alpine aeolian cinder fields, montane dry forest remnants, and leeward mesic shrublands. Natural vegetation of the West Hawaii Island Parks (PUHE, KAHO, and PUHO) has been largely replaced except for coastal strand and wetland vegetation. KALA on Molokai has coastal strand, loulu lelo coastal forest, remnant lowland mesic forest, native vegetation on cliff faces, lowland rain forest, and, in Puu Alii, montane rain forest and wet cliff shrublands.

In the Western Pacific, AMME is covered by alien secondary vegetation and planted ornamentals, except for a wetland and coastal mangroves. WAPA units support coastal vegetation, limestone forest, savanna, and ravine or riverine forest, as well as disturbed areas of secondary vegetation (Fosberg 1960). Piti Guns unit contains a forestry planting of West Indian mahogany (*Swietenia mahogani*), and several other units include maintained lawns and ornamental plantings. The four NPSA units have vegetation ranging from coastal strand and littoral forest to maota mamala lowland rain forest, montane rain forest, and summit scrub dominated by ferns (Whistler 1992, 1994). Mueller-Dombois and Fosberg (1998) suggested that, apart from littoral vegetation, rain and cloud forests were the original vegetation cover of all the islands of Samoa. They interpreted the current vegetation of American Samoa as the result of thousands of years of human disturbance from agriculture and logging.

CONCEPTUAL MODEL

The conceptual model for Vegetation and Flora of the Pacific Islands National Parks follows the general format of Chapter 2. Natural drivers, stressors, and the vegetation attributes affected are listed. Within the description that follows are details of the impacts caused by the stressors and examples of possible indicators. Specific measures to use in monitoring are suggested in the model diagram (Figure 1).

Drivers

Drivers selected for use in the Vegetation conceptual model are the same as those identified for the generalized model of island ecosystems. These are: Organisms, Human Activity, Climate, Relief (Topography), Parent Material, and Time.

Stressors

Stressors are natural or anthropogenic factors that cause measurable system-specific impacts to a suite of attributes. (See definition at http://science.nature.nps.gov/im/monitor/glossary.htm. Significant stressors identified for PACN vegetation include: Drought & severe weather events, Wildfire, Management activities, Adjacent land use, Forest fragmentation, Visitor use & human harvest, Alien invertebrates (insects, slugs & snails), Alien vertebrates (herpetofauna, birds, rodents, and feral animals), Plant disease, Invasive alien plants, Volcanic activity, and Nutrient cycling. The impacts of these stressors on vegetation attributes are discussed below.

Measurable Attributes

Measurable attributes are factors of the natural system impacted by the stressors. (See definition at http://science.nature.nps.gov/im/monitor/glossary.htm. Impacts of stressors on vegetation attributes, as well as specific indicators, are identified below. Appropriate measures and metrics are identified in the conceptual model (Figure 1).

Drought and severe weather events may impact PACN vegetation in a variety of ways. Severe weather events, such as hurricanes and typhoons, impact *Vegetation structure* by opening the forest canopy, decreasing canopy cover, and causing structural damage to large trees. This may lead to loss of important canopy species. Changes in structure lead directly to changes in *Vegetation composition* by increasing light availability and changing conditions to favor alien species over shade-tolerant natives (e.g. ferns, orchids). Drought also changes *Vegetation composition* by favoring drought-tolerant species and vegetation types. This change may be indicated by an increase in grassland areas or a decrease in rainforest cover. Drought may also create conditions intolerable to *Threatened, endangered & rare plants* leading to decreases in population size or extirpation of populations. Changes in *Treeline* due to global warming and drought can be detected through vegetation mapping.

Wildfire affects *Vegetation composition* through loss of native plant species (including *Threatened, endangered and rare plants*); loss of natural biodiversity; and facilitation of alien plant invasions. Wildfire also impacts *Vegetation structure* via loss of tree cover, changing light regime, and forest type replacement.

Management activities, including alien species control and outplanting, impact native communities positively via *Restoration* of target model communities. Management activities can also impact *Vegetation composition* and *Threatened, endangered and rare plants* by increasing disturbance in sensitive areas and decreasing source populations for seed and nursery stock.

Adjacent land use, including encroaching subsistence agriculture, impacts the *size of natural areas* around parks. Loss of contiguous natural areas leads to reduction of habitat for native plant species, loss of corridors for native species, increased invasion of light-loving alien plants along the forest edge, and increased alien bird invasion. Encroaching subsistence agriculture (such as at NPSA) can lead to a loss of integrity of protected rainforest vegetation and, sometimes, direct clearing within the park. This may be indicated by decline of overall forest health and the appearance of crop species within parks.

Forest fragmentation through natural or anthropogenic means creates conditions favorable to light-loving alien species, and changes *Vegetation composition* via loss of shade-tolerant natives, such as ferns, lobelioids (*Clermontia* spp., *Cyanea* spp.), and mints (*Phyllostegia* spp., *Stenogyne* spp.) . Forest fragmentation also reduces populations of *Native bird pollinators* such as apapane (*Himatione sanquinea*), iiwi (*Vestiaria coccinea*), and amakihi (*Hemignathus* spp.).

Visitor use impacts to *Threatened, endangered and rare plants* in heavily visited areas include both trampling of individuals and reduction of overall number of rare plant populations. Examples from HAVO include Hawaiian catchfly (*Silenehawaiensis*) at Crater Rim Trail and ihi makole (*Portulaca sclerocarpa*) at Puhimau Hotspot. Heavy visitor use has also impacted silversword populations at HALE. Human-facilitated introduction and dispersal of alien plant species, especially along trails and roadsides, result in changes to natural *Vegetation composition. Vegetation composition* may also be impacted by Human harvest of culturally significant plant species. The harvest of native fruit bats raises concerns for NPSA vegetation, as these animals serve as important *Native pollinators*.

Alien invertebrates impact PACN vegetation in a variety of ways. *Vegetation composition* is affected by insects, slugs & snails that cause damage to individuals of vulnerable plant species (including *Threatened, endangered and rare plants*), decrease reproduction, and cause unnatural decline in population size. Predatory alien insects (e.g. ants and western yellowjackets, *Vespula pensylvanica*) also impact *native insect pollinators*, resulting in reduced seed set of native plant species.

Alien vertebrates, such as feral ungulates and small mammals, impact *Vegetation composition* via trampling and herbivory of native plants; which leads to loss of natural biodiversity, reduced ground cover, and loss of vulnerable species. Species impacted at HAVO and HALE include: *Clermontia* spp., *Cyanea* spp., koli`i (*Trematolobelia grandiflora*), *Cyrtandra* spp., painiu (*Astelia menziesiana*), hapu`u treeferns (*Cibotium* spp.), Hawaiian catchfly , mamane (*Sophora chrysophylla*), and the bunchgrass *Deschampsia nubigena*. Loss of understory canopy species such as treeferns changes light regimes, impacts *Vegetation structure,* and may lead to loss of vegetation types. Trampling, herbivory, and changing light regimes are particularly hard on *Threatened, endangered and rare plants*, and can lead to reduction of reproduction and recruitment, loss of population stability, reduction of population size, local area extirpation, or extinction. Indicators may include density of preferred forage species, light intensity, numbers of vulnerable species, population structure, and lack or low-numbers of large-fruited native species. Small mammals, reptiles, and amphibians also affect *Vegetation composition* through predation on *native pollinators and seed dispersers*. Alien bird species feed on the fruits, seeds, and seedlings of native plants, thereby affecting both *Vegetation composition* and *Vegetation structure*. Introduced birds also contribute to *Dispersal of alien plants*, such as. blackberry, raspberry (*Rubus spp*).,kahili ginger (*Hedychium gardnerianum*), and banaka poka (*Passiflora tarminiana*).

Invasive alien plants impact *Vegetation composition* through the loss or reduction of both native plant species and natural biodiversity. Loss is indicated by declining native plant cover, extirpated native plant species, and low number of native species/area. Replacement of natives with invasive species interferes with *Natural succession* and changes *Wetland* dynamics. The presence of alien plants results in changes to *Vegetation structure* due to loss of tree cover, changes in light regime, forest type replacement, and reduction in smaller size classes. Indicators may be changes in dominant plant species, or plant species represented exclusively by old or mature individuals. Habitat-altering invasive plant species may also impact *Threatened, endangered and rare species*, leading to extinction or local-area extirpation.

Plant diseases, including pathogenic bacteria, virus, fungi, and nematodes, impact *Vegetation composition* by reducing or eliminating susceptible native plant species (including *Threatened, endangered and rare species*). Where the dominant species in the community are infected, this can lead to changes in *Vegetation structure*, including loss of forest canopy.

Volcanic activity impacts *Vegetation composition*, *Vegetation structure* and *Threatened, endangered and rare* species by causing the stochastic extinction of native plant species with limited distributions and leading to vegetation-type replacement. Volcanic activity is an important component of *soil formation*, and influences *natural succession* processes. Indicators include soil depth and layers.

Long-term Nutrient cycling affects nutrient availability and in turn influences *plant growth and productivity*, *Vegetation structure*, and *Vegetation type*.

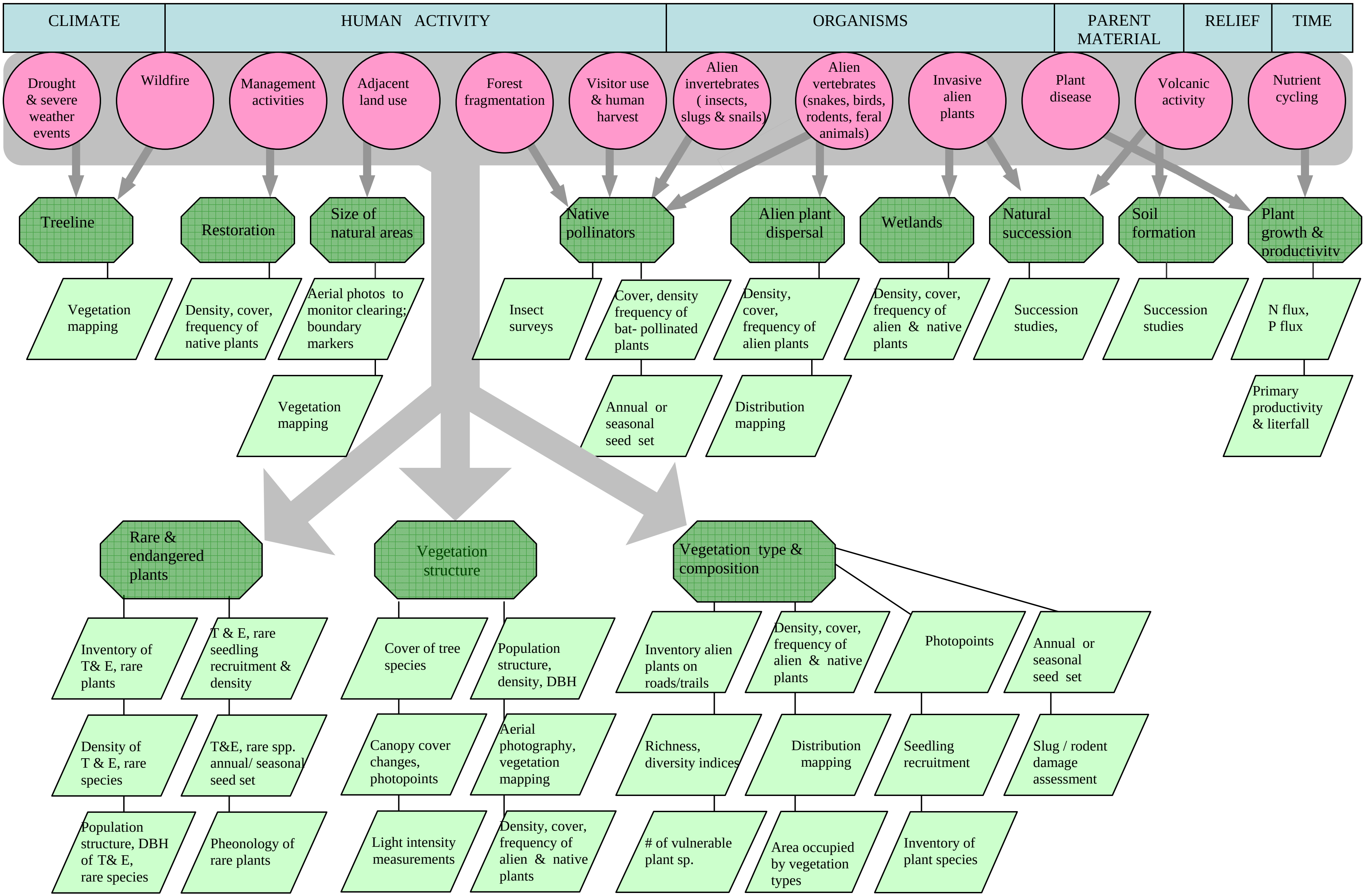

Figure 1: Generalized conceptual model for vegetation in PACN ecosystems:Blue rectangles represent Drivers; pink circles represent Stressors; Dark green octagons represent impacted ecosystem Attributes; and pale green parallelograms list appropriate Measures & Metrics. The three attributes separated and listed on the second row are impacted by a majority of stressors.

Park and Network-Wide Issues

DETECTION AND CONTROL OF INCIPIENT INVASIVE PLANT SPECIES THREATS

All parks face alien species threats. Many threatening species have become established recently in the parks or on the home islands of the parks. Other threats are likely to be introduced to the islands. Some of these species may dramatically alter natural vegetation or vegetation elements of cultural landscapes. Assessing the threat posed by incipient invasive species and detecting their presence are important monitoring functions for Pacific Island parks to insure proactive and cost-effective management.

LOSS OF NATIVE ECOSYSTEMS OR VEGETATION ELEMENTS OF CULTURAL LANDSCAPES THROUGH ALIEN SPECIES INVASIONS

Among Pacific Island parks, alien species invasions have altered many ecosystems and vegetation components of cultural landscapes by displacement of native species and increased habitat fragmentation. Monitoring of changes in native ecosystems and the vegetation components of cultural landscapes allows park managers to understand habitat loss, control alien species, and restore natural vegetation.

LOSS AND RESTORATION OF KEY NATIVE AND POLYNESIAN SPECIES, INCLUDING HARVESTED SPECIES, THREATENED, ENDANGERED, AND OTHER RARE SPECIES

With the loss of native plant communities or vegetation components of cultural landscapes due to invasive species or habitat change, populations of important native and Polynesian species are depleted or locally extirpated. Understanding changes in populations of these key species is important for their restoration or maintenance.

EFFECTIVENESS OF ALIEN SPECIES CONTROL & ECOLOGICAL RESTORATION

Most of the parks have established programs to control alien species and restore native ecosystems or the vegetation components of cultural landscapes. Monitoring is required to understand how the programs have achieved their objectives.

EFFECTS OF HABITAT FRAGMENTATION ON VIABILITY OF KEY NATIVE SPECIES AND PLANT COMMUNITIES

The Pacific Island parks are small landscape elements of their islands. They are often surrounded by developed or managed landscapes or natural landscapes highly altered by invasive species. The long-term viability of key native species and plant communities is problematic in this context. Monitoring is needed to assess changes created by habitat fragmentation and to evaluate efforts to sustain viable systems and populations through partnership programs.

Effects of Disturbance, such as Fire, Hurricanes, Subsistence Agriculture, and Feral Ungulates

These disturbance sources are capable of creating rapid large-scale changes in species composition and community structure. Monitoring is important for understanding these changes and making appropriate management responses.

Effects of Management Programs on Vegetation and Populations

Park management programs for visitor services, infrastructure development, resource protection, and resource harvesting, may affect park plant life. Restoration or alien species control programs may cause both positive and negative changes in park vegetation. Monitoring is needed to understand the impacts of management programs.

Monitoring

Vegetation Mapping

Existing Maps

Vegetation of all the Hawaiian parks has been mapped except for PUHE, ALKA, and USAR. These maps vary in scale and methodology.

HAVO vegetation has been mapped in entirety twice: in 1974 by Mueller-Dombois and Fosberg and by Jacobi *et al*. as part of the USFWS Hawaii Forest Bird Survey in 1979-82. Mueller-Dombois produced a vegetation map of the coastal lowlands in 1980 and other sections of HAVO have been mapped more recently. Loh mapped 90% of HAVO in the 1990s based on 1992 false infrared aerial photography (Loh, in prep.).

HALE vegetation mapping has not been carried out park-wide in one project. Vegetation of the Crater District was mapped at a scale of 1:24,000 by Whitaker (1980). The lower section of Kipahulu Valley below 700 m elevation was mapped by Smith *et al*. in 1985. Jacobi *et al*. mapped most of HALE as part of the USFWS Hawaii Forest Bird Survey (Jacobi 1989). A composite of these three maps was generated, but normalizing the disparate classification schemes allowed for only a very broad classification. Since the early 1990s, vegetation data have been collected using a modification of Jacobi's community descriptions. These description data have been recorded at rare plant observation and outplanting sites throughout the park, including mid-elevation Kipahulu Valley weed transects. The purpose of these descriptions is to obtain ground-truthing data for the creation of a detailed vegetation map.

KALA vegetation has not been mapped in entirety, but the upper forested part of the park, including Puu Alii and some of Waikolu Valley, was sampled by two transects of the USFWS Hawaii Forest Bird Survey (Jacobi 1989). Canfield (1990b) mapped the coastal strand communities of Kalaupapa.

Two of the three West Hawaii Historical Parks have relatively recent vegetation maps. KAHO vegetation was mapped by Canfield (1990a) in 1987, using aerial photographs from 1959 and 1982. Leishmann (1986) mapped PUHO vegetation, using 1976 infrared aerial photographs. Vegetation of both parks was examined on the ground before mapping. Based on later ground surveys in 1993-94, the vegetation of both these parks has changed considerably, and previously recognized mapping units now differ in vegetation structure or dominant plant species (Pratt and Abbott 1996a; 1996b). The vegetation map of PUHO has been recently updated (D. Deardorff, pers. comm. 2003).

In the western Pacific, the vegetation of Saipan has been mapped twice. Falanruw *et al*. (1989) mapped the vegetation of AMME as part of a project covering the islands of Saipan, Rota, and Tinian. Raulerson and Rinehart (1989) produced a map of the vegetation of AMME using a 1987 aerial photograph and data from four transects in the park's wetland. A recent inventory of the mangrove wetland will provide an updated vegetation map (Raulerson and Witteman, in prep.). WAPA vegetation has not been specifically mapped, although general vegetation types within the park units may be recognized on vegetation maps of Guam (Mueller-Dombois and Fosberg 1998). The U. S. Forest Service has recently completed an island-wide survey and map (D. Minton, pers. comm.). Mapping efforts at NPSA include a 1981 coastal management atlas, a vegetation survey and forest inventory (Cole *et al*. 1984), generalized vegetation types in the 1994 GMP, vegetation type maps for Tau (Whistler 1992) and Tutuila (Whistler 1994), and a land delineation effort in 2002 that recognized management and land use categories.

New Maps, using accepted methodology

None of the Pacific Network parks has mapped vegetation according to current Inventory & Monitoring program standards. Jacobi thoroughly mapped HAVO in the late 1970s based on 1977 black-and-white aerial photos, and these maps are available in digital format. Loh mapped 90% of HAVO in the 1990s based on 1992 false infrared aerial photography. These new maps are potentially linkable to the NVCS and are in a digital format.

Fuels Maps

Fuels are characterized and monitored by preparing fuels distribution maps. These indicate the spatial arrangement of fuel types, based on vegetation structural characteristics and known or suspected fire behavior. HAVO has prepared quadrangle-based fuels maps for all but portions of two quads in the southwestern part of the park. Fuels maps were prepared from vegetation maps by combining detailed vegetation units into a smaller number of fuel types. As vegetation and fuels change, vegetation unit or fuel types can be re-monitored or remapped using vegetation mapping techniques followed by classifying new vegetation units into fuels types. The other parks in the network do not have detailed fuels maps. Basic fuels maps can be developed on a small scale. Detailed fuels maps require detailed knowledge of fuels and fire behavior.

RARE PLANT MONITORING

HAVO (exclusive of Kahuku) is known to contain 22 threatened or endangered species native to the park (and several additional endangered species out-planted but not native), as well as 5 candidate endangered species, 22 species of concern, and approximately 40 rare or depleted native species. While many of these have been inventoried as part of Special Ecological Area surveys, few have active or recent monitoring programs. Rare plants of the rain forest were inventoried in the 1990s (Pratt and Abbott 1997, Pratt et al. 1999, Belfield 1998) and baselines exist for future monitoring. Several rare plant species of wet and mesic forest, which are hosts for native pomace flies (*Drosophila* spp.), were monitored for 2-4 years as part of a research project (Pratt and Foote, unpublished data). Similarly, host plants of the native Hawaiian damselfly *Megalagrion koelense* have been monitored biannually from 1992 to 2004 (Foote 2003). Rare plants of montane mesic forests were inventoried (Pratt and Belfield, unpublished), and a subset of 15 species has been recently monitored (Belfield, pers. comm.) Two threatened or endangered plant species of montane and sub-alpine dry forests were monitored for more than five years (Belfield and Pratt 2002); populations of other rare upland plants have been found and mapped but are not currently being monitored. A significant population of the endangered ihi makole (*Portulaca sclerocarpa*) at a geothermal area was monitored at an interval of ten years (Pratt and Abbott, unpublished data), and a second desert population was studied for a shorter period (Belfield and Pratt, unpublished data). Ihi makole declined at both sites; trampling by humans was identified as a possible limiting factor. Rare plants of three remnant lowland dry/mesic forests were inventoried in the 1990s (Abbott and Pratt 1996), and a subset has been monitored as part of a rare plant stabilization project. One endangered species of the lowlands (ohai or *Sesbania tomentosa*) was mapped in the 1990s, and a subset was visited to determine growth and persistence. Density and mortality of another lowland species of concern (the sedge *Fimbristylis hawaiiensis*) were followed in 20 small plots for five years (Belfield and Pratt, unpublished data). The rare plants of the Kahuku addition have not been inventoried, but preliminary monitoring of the endangered Mauna Loa or Kau silversword (*Argryoxiphium kauense*) is underway. Surveys of the most diverse vegetation and older substrates of Kahuku are planned for FY 2004.

At HAVO, volcanic activity is a real or potential negative impact on rare plant populations. This is particularly important for rare and endangered plant species of the forests of Kilauea's East Rift, but virtually every part of the park is vulnerable to lava flows. In prehistoric times, such natural disturbance would likely not have caused the extirpation of a species from a region. Today most rare plants have very limited distributions, and protected natural areas are few and scattered. Therefore lava flows and concomitant wildfires may lead to the loss of rare and endangered species from HAVO, and fires may lead to losses from two of the West Hawaii parks. Monitoring of volcanic activity and dating of lava flows are important aspects of an overall rare plant and vegetation-monitoring scheme.

Rare plant limiting factors research has not been carried out at HAVO, but loss of natural pollinators is thought to be a factor in the rarity of some endangered plant species. A recent monograph of the endemic *Hylaeus* yellow-faced bees (Daly and Magnacca 2003) provided records of visitation by yellow-faced bees to the flowers of several endangered plant species, such as ohai. Basic studies on insect pollinators and seed predators of rare plant species would be worthwhile, and monitoring of alien insects may be an important part of a strategic recovery plan for many endangered plants of HAVO and the other Hawaiian parks. Research on the impacts of alien yellowjacket wasps may identify native insect pollinators that serve as prey of the wasps. Toxicant research may lead to management techniques to reduce the threat of the wasps in native ecosystems (Spurr and Foote 2000; Foote *et al*. submitted). Another group of alien invertebrates that may impact endangered plant species includes slugs and snails. Alien slugs have been implicated as depredators of native plant seedlings, flowers, and fruits (Foote and Pratt, unpublished data). Basic monitoring of slug populations and slug damage to plants may be part of an overall program to monitor rare plants. The contribution of plant diseases to native plant rarity is largely unknown. Basic research has been done to identify diseases of important native plants, such as koa (Hodges and Gardner 1984), mamane (Gardner 1997a), aalii (*Dodonaea viscosa*) (Gardner 1988), and others (Gardner 1997b), but no systematic ecological monitoring of the extent of disease infestation has been carried out in HAVO or the other Pacific Network Parks.

HALE has 15 threatened and endangered plant species extant and five others that have been extirpated. An additional 11 species are candidates for endangered status and at least 22 are species of concern. Approximately 30 additional species are rare, and many of these may be lost in the next decade. It is estimated that 17 plant species have been extirpated from the park; nine of these are now extinct and eight others persist on island (Medeiros *et al*. 1998; S. Anderson and P. Welton, pers. comm. 2003). Monitoring of the threatened Haleakala silversword, one of the best known and charismatic of Hawaii's rare plant species, has been carried out for several decades (Loope and Crivellone 1986). Rare plants of montane bogs were monitored throughout the 1980s (Loope *et al*. 1991; Medeiros *et al*. 1991), and vegetation of the same montane bogs was re-monitored ten years later (Hotchkiss and Werner in prep.). Rare plant species of remnant dry forests were inventoried (Medeiros *et al*. 1986), and data could be used for a monitoring program. Haleakala sandalwood (*Santalum haleakalae*), an uncommon species of the sub alpine shrublands, has been monitored in an exclosure for more than a decade. Rare plants of the montane rain forest of Kipahulu have been sampled on transects and in plots that could be used for monitoring (Anderson *et al*. 1983-86). The Hawaii Forest Bird Survey plot data may be a valuable baseline for rare plants of the montane rain forest. Rare plant observations are currently maintained in a database with information such as number of individuals, size and age class, phenology, alien threats, site description, and GPS location. Rare plant monitoring is one of the priority vegetation monitoring projects (P. Welton, pers. comm.). As at HAVO, research and monitoring of limiting factors are needed to understand the status of many of the rare plants of HALE. Visitor use is probably not an important factor in the decline of the park's endangered plants, but past disturbance and collecting of Haleakala silverswords by visitors was a significant impact on that spectacular species.

KALA Peninsula lowlands and offshore islets support (or formerly supported) at least five endangered plant species, one threatened species and at least eight others that are species of concern. Including the plants of Puu Alii in park totals, KALA has recent or historical records of at least 29 threatened and endangered plant species, 5 candidates for endangered status, and more than 22 species of concern. Additional native species are rare within the park. A monitoring program has been designed for the threatened *Tetramolopium rockii* var. *rockii* and the endangered awiwi (Medeiros *et al.* 2000). Rare plants of Kauhako Crater, including ohe makai (*Reynoldsia sandwicensis*), a species of concern, were tagged, measured, and evaluated in 1995 to provide a baseline for future monitoring (Medeiros *et al*. 1996). Plants of Okala Islet were recently inventoried (Wood and LeGrande 2002); one endangered species, dwarf naupaka, and four species of concern were found. Among the rare species of the islet is a ho`awa (*Pittosporum halophilum*), a tree formerly thought to be extinct. This tree was also recently discovered within the park on the small peninsula of Kukaiwaa. The endangered lobelioid pua ala has been studied and monitored on offshore islands of KALA since 1994 (Gemmill *et al.* 1998; Wood 2002). Ongoing surveys of steep cliffs and inaccessible regions of the park will likely identify additional rare plant resources in KALA.

KAHO has one candidate endangered plant species, a kookoolau (*Bidens micrantha* subsp. *ctenophylla*), and two species of concern. The kookoolau population has declined to few individuals, and the species requires re-introduction rather than monitoring. Recent outplanting of kookoolau will be monitored for survival. One of the species of concern (the sedge *Fimbristylis hawaiiensis*) was monitored in fountain grass removal plots for two years (Pratt unpublished data). There are data on transect frequency and density for pua pilo that could be repeated to monitor the status of this SOC within the park (Pratt and Abbott 1996a). Recently, staff and cooperators inventoried six rare plant species in an 35-ha (86-acre) parcel in the southern part of the park; these rare plants included the candidate endangered kookoolau, the species of concern pua pilo, and depleted common species iliee (*Plumbago zeylanica*), alahe`e (*Psydrax odorata*), and aalii . Individual naio trees (*Myoporum sandwicense*) were previously mapped within the park. Additional rare and endangered plant species appropriate to the coastal lowlands of Kona will be introduced to KAHO in the future, and the success of these restoration projects will be monitored (S. Bond, pers. comm. 2003).

PUHO supports only one known individual of the species of concern pua pilo . A few other native species are rare and depleted at PUHO, but are not considered rare island-wide (Pratt and Abbott 1996b). The endangered coastal loulu palm (*Pritchardia affinis*) has been planted near headquarters. Several endangered species are cultivated in the disjunct upland garden parcel, including a loulu endemic to South Kona (*Pritchardia shautaueri*). There is currently no rare plant monitoring ongoing.

PUHE has no naturally occurring threatened or endangered plant species, but ohai historically occurred within the park (D. Kawaiea, pers. comm. 2003). Three endangered plants and one species of concern have been planted in the park: ohai; mao hau hele (*Hibiscus brackenridgei*); loulu (*Pritchardia affinis*); and mao or Hawaiian cotton (*Gossypium tomentosum*) (Pratt and Abbott 1996c). A population of the rare pololei fern has been monitored by park staff for more than a decade.

AMME has no listed threatened or endangered plant species, but at least one orchid species (*Zeuxine fritzii*) has been identified as rare within the park (Raulerson and Rinehart 1989).

WAPA had its first comprehensive vascular plant inventory in 2004; approximately 350 species were documented in the park (Yoshioka in prep.). The rare moonseed vine *Tinospora homosepala* was recently reported within the park (D. Minton, pers. comm.), and was confirmed present at Asan Beach in the 2004 inventory. This vine is currently listed as a Species of Concern by the USFWS. It is unlikely that the park supports the only Federally-listed endangered plant species recognized on Guam (*Serianthes nelsoni*), as this species is thought to be extant only in the northern section of the island (USFWS 1994). However, the type locality of *S. nelsoni* is “Upe District and hills back to Abu” (Stone 1970), a site near Mt. Tenjo. The tree fern tsatsa (*Cyathea lunulata*) has not been found in the park, but may occur in protected ravines within savanna vegetation of WAPA; the species is recognized as endangered by the Government of Guam and is considered very rare on Guam (Raulerson and Rinehart 1992). One or more of the four orchid species endemic to Guam and the Mariana Islands may grow within the park, but have not yet been documented in any unit. *Tabernaemontana rotensis,* a candidate endangered species (USFWS 2004), is known from few limestone forest sites on Guam and is probably not a component of park vegetation. Rarity of the park's native plant species should be evaluated and a list of sensitive native plants developed before comprehensive monitoring is undertaken. Typhoons are a frequent disturbance factor on Guam and may impact populations of rare plants or their habitat in the park units. Investigation of the effects of such storms should be a component of a rare plant monitoring scheme.

Monitoring of the alien Brown Tree Snake is relevant to rare plants on Guam and indirectly to those of Hawaii. Native songbirds are important agents of pollination and seed dispersal, and the bird populations of Guam have been decimated by the brown tree snake. If bird-eating snakes become established in the Hawaiian Islands, rare plant populations may be negatively affected. Efforts to detect incipient invaders such as snakes are critical to the long-term survival of native birds and rare plants in the Hawaiian Islands (Kraus and Cravalho 2001).

NPSA has benefited from recent plant inventories of its three units (Whistler 1992, 1994). None of the vascular plants of the park is listed as endangered, but a list of plants rare in NPSA and on the islands of Tutuila and Tau could be generated from Whistler's checklists. Four species collected on Tutuila (*Elatostema tutuilense*, *Habenaria monogyne, Litsea samoensis*, and *Manilkara dissecta*) and one species from Tau (*Acronychia retusa*, now known as *Melicope retusa*) are currently considered Species of Concern (USFWS2004). Three of these five rare species are known to occur within at least one park unit. An evaluation of the rarity of native plants of American Samoa and recommendations of species deserving of threatened and endangered status were recently provided by Whistler (2003). No rare plant monitoring is underway, but the vegetation plots of Whistler (1994) or Heggie and Cairns (2001) might be used for future monitoring of rare tree species.

ALIEN PLANT MONITORING

With more than 600 species of alien plants known from HAVO (Higashino *et al*. 1988a), alien plant monitoring must be an important component of the park's vegetation inventory and monitoring program. HAVO has many current and past monitoring projects that involve alien plants. They are of three basic types: distribution and frequency transects or mapping projects, alien plant treatment effectiveness monitoring, or monitoring of alien species in vegetation community studies. Recently, a series of research projects have focused on characteristics or negative impacts of single alien plant species.

Alien plant frequency transects have been established in the Mauna Loa Strip, Olaa Forest managed units, East Rift forests (Pratt *et al.* 1999), Kipuka Puaulu and Kipuka Ki, Thurston SEA, and Kipuka Kahalii (Pratt, unpublished data). A number of alien plant mapping projects were accomplished as a first step in the development of control and containment strategies (Tunison 1992a). Firetree or faya , banana poka , and blackberry/raspberry were the focus of island-wide distribution maps that included HAVO (Whiteaker and Gardner 1985, 1992; Warshauer *et al*. 1983; Gerrish *et al*. 1992). A more recent effort was made to map the current park distribution of faya or firetree (Camrath *et al*. 1997). The distribution of fountain grass was mapped in and near HAVO, and control strategies were developed to contain and eventually eradicate this highly invasive species from the park (Tunison 1992b). Alien grass communities of the park's coastal lowlands were mapped by Mueller-Dombois in 1982. Localized alien plant species within HAVO were mapped throughout the park (Tunison *et al*. 1992) and on roads and trails in and near the park (Stemmermann 1987). Common mullein (*Verbascum thapsus*) was recently surveyed in the Mauna Loa Strip, where it has been established since the 1970s (Loh *et al*. 2000). Recent monitoring of invasive alien plants has been carried out along primary and secondary roads in HAVO (Bio *et al*., in prep.) and on park trails (Benitez, in prep.). The role of visitors as distributors of weed seeds along trails during organized races was addressed by Higashino *et al*. (1983). Monitoring of seeds brought in on the shoes of runners has continued sporadically for 20 years.

Alien plant treatment effectiveness monitoring has been carried out by Resources Management personnel, and detailed results of experimental herbicide trials and larger tests of management techniques are contained in RM files. This RM alien plant monitoring has been concentrated in Special Ecological Areas (SEAs), which contain the most important natural resources of the park and receive the most intensive management attention (Tunison *et al.* 1986). Many alien plant monitoring projects have been focused on finding effective treatments for suites of weed species that have invaded Olaa Tract, Kipuka Puaulu, Kipuka Ki, the Crater Rim forests near Thurston Lava Tube, Ainahou Ranch, Naulu Forest, the Keamoku lava flow, and more than ten other areas. Monitoring was established to follow changing frequency or density of alien plants after control efforts, particularly in Olaa Forest, Kipuka Puaulu, and firetree-infested woodlands (Tunison and Stone 1992). Techniques to kill localized alien plants have also been investigated (Tunison and Zimmer 1992). Over the last two decades, several research projects focused on determining efficacy of various herbicides and application rates (Eldredge and Gardner 1984; Santos *et al*. 1986, 1992). Some of the most highly invasive alien plants in the park, such as banana poka, yellow Himalayan raspberry (*Rubus ellipticus*), firetree, and strawberry guava (*Psidium cattleianum*), were studied in multi-year research projects involving herbicide tests (Gardner and Kageler 1982; Santos *et al*. 1991a, 1991b; Cuddihy *et al*. 1991; Pratt *et al*. 1994).

Many studies of plant communities in HAVO have an alien plant-monitoring component. Park Naturalists G. O. Fagerlund and A. L. Mitchell pioneered early vegetation studies in HAVO. The archives and research files have copies of some of these studies, such as a quadrat-charting project established in the coastal lowlands. Checklists of alien (exotic) plant species in the park (Fagerlund 1947; Fosberg 1966) give us information on introduction dates and original range of many weeds. The International Biological Program or IBP (Mueller-Dombois 1970; Mueller-Dombois *et al*. 1981), the Ohia Dieback Project (Mueller-Dombois 1974, 1977, 1980, 1985), and the Hawaii Forest Bird Survey (Scott *et al*. 1986; Jacobi 1990) supported studies in HAVO that involved vegetation monitoring with an alien plant component. Succession studies of invasion and recovery of vegetation after the 1959 Kilauea Iki eruption documented the timing and invasive potential of alien plant species on new substrates (Smathers and Mueller-Dombois 1974). Follow-up studies in the same area monitored the success and population structure of native and alien shrub species (Wright and Mueller-Dombois 1988) and examined the association of firetree with other alien plants (Mueller-Dombois and Whiteaker 1990).

Much preliminary ecological data, including information about alien plants and vegetation, were collected within HAVO in the early 1960s and summarized by Doty and Mueller-Dombois (1966). In the 1980s, vegetation was sampled at several sites along the East Rift of Kilauea near the park's boundary with Kahaualea to establish a baseline prior to proposed geothermal development (Cuddihy *et al*. 1986). In the 1990s, vegetation, bird, and insect monitoring projects were focused on newly designated SEAs (Stone 1990); the results of some of these studies remain unpublished. Weed frequencies were mapped along transects in several SEAs; at some sites, frequency data were compared with results from earlier sampling along the same transects. Forests of the East Rift (Pratt *et al*. 1999), Naulu, Kealakomo (Abbott and Pratt 1996), and Olaa (Pratt and Abbott, unpublished) were the focus of several monitoring projects that included alien plant monitoring, as well as assessment of recovery from feral animal damage and monitoring the distribution and abundance of rare native plant species.

A number of studies have been focused on firetree or faya and its impacts on native plant communities and ecosystem processes. Vitousek and Walker (1989) detailed growth and germination patterns of firetree and investigated its input of nitrogen to the ecosystem. Walker and Vitousek (1991) studied the direct impacts of firetree on the dominant native tree ohia lehua . Lipp (1994) investigated ecophysiological constraints to the invasion of firetree into montane rain forests and dry lowland areas. More recently, a collection of technical reports summarized research and management of firetree in HAVO (Tunison, in prep.). Currently, dense faya stands in the park are the subject of research that includes a management technique component and incorporates seed bank studies and monitoring of surrounding vegetation (Loh 2004).

Other alien plants have received considerably less research attention. Banana poka was the subject of research that included Olaa Tract as a study site (LaRosa 1984, 1992). The spread of yellow Himalayan raspberry within Olaa Forest was evaluated by Stratton (1996). Recently, common mullein distribution and density were mapped on the Mauna Loa Strip, and potential control methods were assessed (Loh *et al.* 2000). Studies of alien birds as dispersers of weeds may also contribute to the design of a monitoring program (Kjargaard 1994; LaRosa *et al*. 1985). The role of alien birds as seed predators has not been fully investigated, but one new research project will attempt to document the role of introduced kalij pheasants (*Lophura leucomelanos*) as seed consumers and dispersers (Pratt and Hu 2002; Postelli, unpublished data.). A few weed germination studies have been carried out by Resources Management personnel, and one seed bank study at a lowland forest of Kealakomo monitored seed rain and analyzed seed banks of native and weed species (Drake 1998).

The most recent published checklist of flowering plants and gymnosperms in HALE documents 301 alien species (Medeiros *et al*. 1998); this amounts to 53% of the park's flowering plant (and conifer) flora. This list does not include plants of the recently acquired Kaapahu parcel that is currently being inventoried (Welton and Haus, in prep.). An earlier assessment of the worst alien plant invaders and strategies for their control recognized 334 introduced vascular plant species in HALE (Loope *et al*. 1992). Few alien fern species are found in the park. Herat *et al*. (1981) listed only two non-native ferns in the Crater District, and a checklist of Kipahulu Valley contained only 9 alien species of a total 98 fern taxa (Higashino *et al*. 1988b). Similarly to HAVO, HALE alien plant monitoring falls into several categories: vegetation mapping, distribution and frequency monitoring, alien plant treatment monitoring or research into control techniques, alien plant species within the vegetation community, and impacts of individual alien plant species. Old checklists are valuable historical documents and allow determination of the approximate timing of alien plant invasions and intensification. HALE has one checklist of vascular plants of the Crater District (then Haleakala District of Hawaii National Park), dating from 1945 (Mitchell). Another set of checklists resulted from the Resources Base Inventory or RBI (Stemmermann *et al*. 1981 and Herat *et al*. 1981). Kipahulu Valley was inventoried before it was added to HALE (Lamoureux in Warner 1967), and there were additions and updated checklists of the Valley's flora (Lamoureux and Stemmermann 1976; Higashino *et al.* 1988). HALE staff maintains a current updated plant species list (Haus *et al*., unpublished data).

Data on weed distribution and estimated abundance were collected within plots at stations on transects throughout the park, (within both the Crater District and Kipahulu Valley), as part of the Forest Bird Survey (Jacobi 1989). Alien plant frequency transects were established in 1983 as part of an interdisciplinary study and were continued and expanded as part of a feral pig study. Weed data were summarized by Anderson *et al*. (1992). Information on weed distribution in Kipahulu Valley was provided by Yoshinaga (1980) prior to the interdisclipinary study, so there are repeated weed data sets for the area. A long transect on the edge of the upper plateau in Kipahulu was used to track alien plant distributions along a heavily used trail (Medeiros *et al*. 1992). Australian tree ferns (*Sphaeropteris cooperi*) were studied in large quadrats at 730 m (2,400 ft) elevation in the lower Kipahulu Valley (Medeiros *et al*. 1992, 1993). Between 1990 and 2003, four long transects, stretching from 670 to 1,400 m (2,200-4,600 ft) elevation, and six short 500-m-long transects were established in the lower Kipahulu Valley rain forest to monitor weed distributions and frequencies. Currently, weed distributions and densities throughout the park are recorded, along with alien plant control efforts, in a GIS-linked Access database (Welton, Haus, *et al.*, unpublished). Bog vegetation, including alien plant species, was monitored in several bogs within and near the park (Medeiros *et al*. 1991, Loope *et al*. 1991).

In the Crater District of HALE, alien plants were monitored as part of a study at Puu Mamane (Loope and Medeiros, unpublished data), and baseline data on alien cheatgrass (*Bromus tectorum*) were collected in each of Whiteaker's (1980) vegetation units in 1993 (Loope and Medeiros, unpublished data). The distribution of cheatgrass in the Crater District was mapped in the mid 1990s (Weller 1993). Within Kaupo Gap, transects and plots sampled vegetation, including alien species (Medeiros and Jessel, unpublished data 1987). Six transects were established in Kaupo Gap to monitor cover of molasses grass (*Melinis minutiflora*) (Medeiros and Loope, unpublished data 1989). Vegetation plots were established in Kaupo Gap in the 1990s to monitor aalii stand structure , restoration of vegetation , and the efficacy of the monocot-specific herbicide Fusillade on molasses grass and native shrubs. Weeds, particularly alien grasses, were a component of several studies in the high-elevation grasslands of Kalapawili carried out by Jacobi (1981), Medeiros and Nishibayashi (unpublished 1986), Medeiros and Jessel (unpublished, 1987), and Anderson *et al.* (1992). Coastal strand vegetation was monitored to detect alien plant invasion in one small area of native vegetation (Medeiros and Jessel, unpublished 1990), and the native annual grass *Panicum fauriei* var. *latius* was followed inside an exclosure near Puhilele Point (Welton, unpublished 1993). Exclosures were built to document recovery of native vegetation from damage by feral ungulates in several ecological zones of HALE; there is typically an alien plant-monitoring component to these projects (Loope and Scowcroft 1985).

KALA does not yet have a specific monitoring program to evaluate alien plant species throughout the park, but several established projects at Kauhako Crater (Medeiros *et al*. 1996) and in the coastal zone of the park (Canfield 1990) addressed alien plant species and could be replicated as part of a monitoring program. Monitoring designed to follow rare plants in exclosures (Medeiros *et al.* 2000) could be used to determine the impact of alien plants on the endangered awiwi and the threatened *Tetramolopium rockii* var. *rockii*. A monitoring program has been designed to track survivorship, threats, and pollination success of the endangered pua ala and dwarf naupaka on offshore islets at KALA, and weeds of offshore islets have been evaluated (Wood 2002, unpublished; Wood pers. comm. 2003). At least two transects established during the Forest Bird Survey 25 years ago were placed within or near the upper reaches of KALA, and these may provide some data on the presence/absence and relative abundance of alien plant species in the park's rain forest. Surveys of inaccessible areas of KALA planned for FY2004 will also provide data on alien plant threats to rare native species.

Vegetation at the three West Hawaii Historical Parks is dominated by alien plant species. PUHO has a long history of alien plant control since its establishment in 1961. The area near the Visitor Center and the Great Wall of the Puuhonua has been repeatedly cleared of alien vegetation, and several additional significant historical sites within the park are currently the focus of alien plant control efforts. More than half of PUHO remains covered by alien shrubland, which is dominated by koa haole mixed with other shrubs and grasses, particularly Guinea grass (*Panicum maximum*). Monitoring of alien plants at PUHO consists primarily of treatment effectiveness monitoring. In 1992-94, a set of systematic transects was established throughout the park, along which weed frequency and estimated cover-abundance data were collected (Pratt and Abbott 1996a). These baseline data might be used in a monitoring program to determine trends in alien plant cover. The vascular plant checklist generated during the 1992-94 project, along with an earlier list from a survey in 1982-83 (Smith *et al*. 1986), provides a baseline of the park's current floral composition and may be used to document future incursions of alien plants.

KAHO, although a newer addition to the Park Service, also has a relatively large portion of the park targeted for alien plant control. There is currently no alien plant monitoring being carried out, other than informal evaluation of treatment effectiveness. Fountain grass has been cleared from several sites near Kaloko Pond. Fountain grass and assorted alien shrubs are routinely removed from the 1.5 km stretch of the Mamalahoa Trail that crosses the park; several other trails along the coast and around Kaloko Pond are also maintained by clearing alien plants. Alien grasses and shrubs have been recently controlled in 3 ha (7 a) along the new interpretive trail to Honokohau Beach; mechanical clearing allowed existing native plants to remain undisturbed. These recent alien vegetation-clearing projects used park staff, PCSU personnel, Hawaii Emergency Environmental Workforce crew, and YCC student workers. Clearing of invasive plants has fulfilled park goals of fire management, visitor safety, ecosystem restoration, and protection of cultural sites (Stan Bond, pers. comm. 2003). The General Management Plan (1994) proposed eventual clearing of most alien vegetation and its replacement with native or culturally important plant species. Vegetation sampling before and after alien plant clearing would assist with evaluation of treatment effectiveness and allow for development of efficient re-treatment schemes. It would also be worthwhile to document the appearance of newly invasive alien plants and the relative cover of native and alien plants at some sites of high natural value (i.e. wetlands near Aimakapa and vegetation surrounding anchialine pools). In a project similar to that at PUHO, seven systematic transects were established crossing the park from the upper boundary to the coast. In 1992-94, weed frequency and estimated cover-abundance data were collected in a belt along transects (Pratt and Abbott 1996b). These baseline data might be used in a monitoring program to determine trends in alien plant cover. A vascular plant checklist was developed during the 1992-94 project and revised several years later (Pratt 1998). Comparisons with an earlier checklist from a survey in 1988 (Canfield 1990) indicated that alien plant species continue to appear in KAHO as invaders from nearby areas, particularly along roads, trails, and in disturbed areas.

PUHE is the smallest of the west Hawaii Historical Parks and has the most altered vegetation of the three. Only the coastal strand and brackish pool support native vegetation within the park (excepting plantings of native species near Headquarters buildings). The park has a recent checklist of vascular plants, but no baseline vegetation monitoring was established during the last plant survey (Pratt and Abbott 1996c). In a previous survey of the vascular plants of PUHE, Macneil and Hemmes (1977) established 19 transects (15-m long) at 100 m intervals along Highway 27 and the old Spencer Beach Road (see also Croft *et al*. 1976). The purpose of the monitoring was to detect roadside introductions of alien plants; the method used was measurement of percentage cover of plants in 1-m2 quadrats at 2-m intervals along transects. Transects and plots were not located during the most recent plant survey, but the methods of Macneil and Hemmes could be replicated and monitoring data compared with that collected almost 30 years ago. Currently, alien plant removal projects are focused on several priority species that are invading a coastal wetland (pickleweed) or interfering with the viewscape from the imposing Puukohola Heiau (kiawe). Widespread weeds, such as buffelgrass (*Cenchrus ciliaris*), or highly invasive species still localized in PUHE (fountain grass; puncture vine, ; and koa haole,) are treated in portions of the park (Amerling 1997). Other alien plant species are kept from growing on archaeological sites or trails. There will likely be an alien plant component in current and future restoration projects, such as the rehabilitation of the area formerly covered by a roadway that passed through the park at the base of Puu Kohola Heiau.

At AMME, Raulerson and Rinehart (1989) installed four transects in wetland vegetation along which they collected frequency and cover data on all plant species. They used these data to calculate importance values for all plant species in four strata along each transect. As many of the plants encountered on two of the four transects were weedy species not native to Saipan, this research may be considered a baseline alien plant monitoring project. Non-native trees planted as ornamentals near park structures have not been recently evaluated. The recent inventory of vascular plants at WAPA provided a list of alien plants present in the park, although the report is not complete and some specimens have not yet been identified. Approximately half of the documented monocots and dicots are alien species, including both naturalized and cultivated plants; only one alien fern was found in the park (Yoshioka, in prep.). Many of the alien monocots are members of the grass family (Poaceae). No monitoring of alien plants has been undertaken at WAPA, but a current research project focused on savanna vegetation may provide some baseline information on both native and alien plant species (D. Minton, pers. comm. 2003). One recent proposal submitted as part of an unfunded rehabilitation plan following Supertyphoon Paka recommended establishment of photo points at Agat Invasion Beach and the Asan Bay overlook. The proposal involved use of archived photographs from 1944 as baselines for comparison with modern photographs. The goals of the project were to monitor the historic scene, recovery of vegetation, and weed invasion (Anderson 1998). The frequency and severity of typhoons relate to the invasion and increase in cover of alien plant species. Monitoring the impacts of typhoons on the vegetation structure and plant composition of Guam forests may be an important part of any alien plant monitoring scheme developed for the park units.

The vegetation of three of the four NPSA units was described by Whistler (1992, 1994). Checklists produced for Tutuila and Tau are very thorough and distinguish plant species documented within the park from those on the islands likely to be present. Ninety-six non-native plant species are found on Tutuila; most of these are members of the grass (Poaceae), sedge (Cyperaceae), daisy (Asteraceae), and pea (Fabaceae) families (Whistler 1994). There are approximately 85 alien plant species (modern introductions) on Tau, along with 40 Polynesian introductions and 329 native vascular plant species. The most invasive alien plant species noted by Whistler (1992) on Tau were Koster's curse (*Clidemia hirta*), a newly established weed, and mile-a-minute vine (*Mikania micrantha*), which has been present in Samoa more than 100 years. Other alien species reported from western Samoa, but not yet in American Samoa are of concern; one of the most invasive is African rubber tree (*Funtumia elastica*) Highly invasive alien plants already present in American Samoa include giant sensitive plant (*Mimosa invisa*) and night-blooming cestrum (*Cestrum nocturnum*). More recently, Space and Flynn (2000) reported on 30 invasive alien plant species commonly found in NPSA and recognized 25 additional alien species that are potentially aggressive. Apart from 11 vegetation plots on Tutuila and one on Tau, the Samoan plant inventories did not result in a system to monitor alien plant cover or abundance. Whistler focused on native tree density and basal area and did not sample ground cover or alien vegetation, but the sample plots are potentially valuable for monitoring native trees. Recently, albizia (*Falcataria moluccana*) has invaded NPSA, and has been mapped and partially controlled on Tutuila. A proposal to control and eliminate the tree from the park has been developed (Monello 2003a). Alien plants and Polynesian introductions may be used to identify secondary vegetation on formerly cultivated lands within park units.

Recovery of Vegetation after Feral Animal Removal

HAVO and HALE have expended great effort over the last three decades to remove feral animals from areas with high natural value (SEAs in HAVO, Kipahulu Valley and Haleakala Crater in HALE). At HAVO, feral goats (*Capra hircus*) have been largely eradicated, and feral pigs have been fenced out and removed from approximately 1/3 of the park's rain forest. Mouflon sheep (*Ovis musimon*) are recent invaders, and are difficult to exclude by standard fencing. Domestic and feral cattle (*Bos taurus*) were removed from HAVO more than 50 years ago (25 years for the Ainahou Ranch in-holding), except for temporary incursions from adjacent ranches and the occasional feral cow in East Rift forests. HALE shared the same suite of feral ungulates, and has had spectacular results with projects to build exclusionary fences and remove feral goats and pigs. Axis deer (*Axis axis*) are a potentially serious threat to HALE vegetation, although the species does not seem to be established yet within the park.

Domestic cattle were the focus of early studies of the impacts of ungulates on native vegetation in HAVO (Baldwin and Fagerlund 1943). After the removal of cattle from the Mauna Loa Strip in 1948, cattle were not a significant disturbance factor in HAVO. Recently, plots from the cattle and koa forest study in the 1940s were relocated and monitored (Tunison *et al*. 1995a); this effort allowed the 50-year old plots to contribute to a long-term data set. One research project compared grasslands and shrublands protected from cattle inside the park with those in adjacent ranchland (Cuddihy 1984). In the last three decades, HAVO monitoring of vegetation recovery has been focused on feral pigs in rain forest, and goats in subalpine shrubland, montane dry/mesic forests, and lowland grasslands. Feral goats formerly occurred in great numbers in the coastal lowlands; an eradication program began in 1970 (Baker and Reeser 1972) and successfully removed goats from the lower reaches of the park within a decade. Two exclosures were built (at Kukalauula and Puu Kaone) to monitor recovery after goat removal; monitoring continued for ten years (1971-1980) (Mueller-Dombois and Spatz 1972, 1975; Mueller-Dombois 1981). Subsequently, exclosures and 14 grassland transects were sampled for an additional six years (Stone *et al*. 1992).

Before feral goats were excluded from the Mauna Loa Strip, the recovery of koa was monitored inside a goat exclosure (Spatz and Mueller-Dombois 1972, 1973). Feral goats were removed from units of the Mauna Loa SEA in 1985 (Katahira *et al.* 1993). Recovery of montane koa forest vegetation was monitored using 20 pairs of plots above and below an exclusionary fence at 2,070 m (6,800 ft) elevation (Stone *et al*. 1992; Tunison, unpublished data). Another set of vegetation plots was systematically placed along transects between Kipuka Ki and the upper fence in the mid 1980s (Tunison and Pratt, unpublished data). Three transects monitored recovery of native grasses and shrubs in Kipuka Maunaiu and Kipuka Kulalio above and below the upper fence (Stone *et al*. 1992). Recently mouflon sheep have invaded the subalpine and montane forest of the Mauna Loa Strip. One rare plant monitoring study demonstrated serious damage to the threatened Hawaiian catchly caused by mouflon (Belfield and Pratt 2002). Two tagged populations of this species could serve as long-term monitoring for recovery . Another Hawaiian catchfly population inside and outside a razor-wire exclosure was monitored for a year and could function as a baseline for future monitoring.

Historically, the most damaging feral ungulate in HAVO rain forests has been the pig. Numerous studies have focused on the impacts of this destructive alien animal on Hawaiian rain forests, and HAVO management units have provided data on recovery of forests after feral pig removal. Olaa Forest is the site of most studies of vegetation recovery after pig removal (Stone *et al*. 1992; Loh and Tunison 1999; Pratt and Abbott, in prep.). One monitoring project was carried out for more than two years in forests of Kilauea’s East Rift (Pratt *et al*. 1999); the 29 pig-disturbed vegetation plots established for this study might be relocated for continued monitoring, although some of the plots were in forest that burned in June, 2003. Pig activity transects have been established within rain forests of both Olaa and the East Rift, and quarterly to annual surveys were undertaken between 1985 and 2003 (Stout and Foote, in prep.). Exclosures have been used to monitor rain forest recovery at several sites in HAVO, including Olaa, the East Rift, and the Fern Forest near Thurston Lava Tube (Higashino and Stone 1982; Loope and Scowcroft 1985). Feral pigs have also impacted dry and mesic forest vegetation of the Mauna Loa Strip. The effects of feral pigs on grassland succession were investigated by Spatz and Mueller-Dombois (1972). Changes in vegetation in pig-disturbed plots were monitored for seven years at several Mauna Loa Strip sites (Tunison *et al*. 1994a).

HALE resource managers have been highly successful at removing feral goats and pigs from the park. Many monitoring projects established to determine vegetation trends may now be used to document recovery after feral animal removal. Monitoring of threatened Haleakala silversword, which has continued after removal of feral goats from Haleakala Crater, provides information on population size of the rare plant (Loope and Crivellone 1986), although Kobayashi (1973) did not consider goat depredation a serious limiting factor of the species. Other vegetation monitoring projects within and near the Crater, such as quadrats at Puu Mamane and amau (*Sadleria cyatheoides*) plots at Halemauu Pali, provide information on recovery after removal of feral goats. Evaluation of an exclosure in the Crater between the Bottomless Pit and Paliku detected no reproduction of mamane after ten years of protection (Jacobi 1980). An exclosure on the west slope established to protect Haleakala sandalwood and mamane documented slow changes in native vegetation after exclusion of feral ungulates. Another exclosure in West Kaupo monitored changes in native shrubland with protection from goats (Medeiros *et al*. unpublished). Dry forests in and near HALE were the subjects of a rare plant survey almost 20 years ago (Medeiros *et al*. 1986). Those areas now free of feral animals might be re-surveyed for rare plants.

One exclosure in Kalapawili grasslands documented recovery following protection from feral pigs (Jacobi 1981). Other transects in the grasslands were used to monitor vegetation before and after exclusion of pigs and goats (Anderson *et al*. 1992, Medeiros, unpublished data). Montane bogs fenced to exclude feral pigs were monitored for seven years by Loope *et al*. (1994); other unprotected bogs were also monitored by Medeiros *et al.* (1994). Earlier studies of HALE bogs are also available (Vogl and Henrickson 1969). The impacts of feral pigs on rain forests of Kipahulu Valley were studied by Diong (1983). Transects and vegetation plots established in the valley prior to removal of feral pigs may be used to demonstrate recovery of vegetation (Anderson *et al*. 1992; Anderson 1995; Medeiros *et al*. unpublished data). Data from the Forest Bird Survey more than 20 years ago may also document vegetation changes.

The vegetation of KALA is threatened by feral goats, pigs, and axis deer, although the latter species appears to be the most damaging to park resources. Domestic cattle and horses (*Equus caballus*) have also recently inhabited the park (Canfield 1990b). Exclusionary fences have been constructed around Kauhako Crater and surrounding rare plants of the coastal strand. Currently, park staff members are cooperating with Hawaii State DLNR, The Nature Conservancy, and Kamehameha Schools to carry out joint fencing projects in upslope rain forest that will benefit the park and other conservation lands. Baseline monitoring of ground and canopy cover within the dry forest of Kauhako Crater was initiated in 1995, prior to fencing and removal of feral ungulates (Medeiros *et al.* 1996). This community-level monitoring, as well as measurements and evaluation of rare tree species, may be replicated in the future as part of a vegetation recovery project. Canfield (1990b) recommended that several exclosures be constructed to protect different plant associations of strand vegetation. Monitoring in and outside of exclosures may helpto determine the impacts of domestic and feral animals on both native and alien plants of the coastal vegetation.

At present, the three West Hawaii Historical Parks have no persistent feral ungulate populations within their lands. However, portions of all three parks were formerly used to graze cattle and goats. PUHO has a boundary fence to keep out domestic cattle and feral sheep. Feral pigs have damaged wetlands at KAHO in the recent past, but managers removed the animals. Grazing animals are excluded from PUHE by ranch fences upslope of the park. The status of feral ungulates along the trail of ALKA is currently unknown.

AMME on the island of Saipan does not have feral ungulate populations or shared boundaries with areas supporting domestic cattle. WAPA on the island of Guam undoubtedly has populations of feral pigs and Philippine deer living within some of its units. Carabao or water buffalo (*Bubalus bubalis*) may also inhabit some of the ravine vegetation adjacent to river systems within the park. No monitoring of feral animal impacts has been done within the units of WAPA. If feral animal control is accomplished within any of the park units containing limestone forest, monitoring of native tree reproduction in these remnant forests would be a useful project to help guide future vegetation management.

NPSA units support populations of feral pigs, an ungulate species that was introduced to Samoa thousands of years ago by Polynesian settlers. Whistler (1994) considered feral pigs to be a problem in the Tutuila unit. Before hunting declined, pig population levels were reduced by local hunters. Feral pigs are also a pest on Tau, where they damage cultivated crops, leading to abandonment of upper-elevation fields (Whistler 1992). Park staff members are currently monitoring pig activity transects, at least on Tutuila (Stassia Samuels, pers. comm.).

ALIEN RODENTS

Rats and mice are not native to the Hawaiian Islands, although the Polynesian rat (*Rattus exulans*) was an early arrival with thePolynesian discoverers of Hawaii. The black or roof rat (*Rattus rattus*), in particular, has been implicated as a seed predator and consumer of many native plant species (Stone 1985). The distribution of rodents was monitored along several elevational transects on Mauna Loa as part of the International Biological Program (IBP) in HAVO (Tomich 1981). Distribution, density, population composition, and food habits of rats were monitored in several SEAs of HAVO in the late 1980s. A preliminary study of the use of toxicants to temporarily reduce rats in a mesic forest was also made (Forbes and Stone 1997; Stone unpublished data 1986-1990). This was followed recently with an intensive evaluation of the efficacy of broadcast toxicants (Spurr *et al*. 2003a, 2003b). Out-planted seedlings and trays of native seeds were monitored for two years as part of this study (Foote and Pratt, unpublished data). Vegetation in the wet and mesic forest study areas was monitored before and after the toxicant study. Food habit studies of introduced rats have also provided information on consumption of native plants and seed predation (Russell 1980; Sugihara 1997). Rats are seed predators of both common and rare plant species in the park (Baker 1979; Male and Loeffler 1997).

Monitoring of rat populations was also carried out in HALE in 1983-84 as part of the Kipahulu Interdisclipinary Study (Stone *et al*. 1984). Rodent food habit studies were accomplished at HALE, and reductions of native arthropods were demonstrated. Few direct impacts on native plants were documented, although seed predation by rats was observed (Cole *et al*. 2000). Sugihara (1997) studied rat populations and food habits in Hanawi Natural Area Reserve, adjacent to HALE. Data on rat predation are collected in current HALE rare plant monitoring programs. Additional monitoring of the impacts of rats on rare plant populations in both HALE and HAVO is warranted.

Assessment of rodent and mongoose populations was part of a monitoring project in all three of the West Hawaii Island Historical Parks, but the impacts of rats on native plants was not part of the study (Stone, unpublished data 1992-1994). Even though the vegetation of the three parks (KAHO, PUHO, and PUHE) is largely alien, rodents may be impacting large-seeded native species in the parks. Plants suffering from rodent seed predation likely include naio , pua pilo (a species of concern), and the endangered loulu palm (*Pritchardia affinis*).

No rodent monitoring has been carried out at KALA, but Medeiros *et al*. (1996) recommended studies to determine the impacts of rodents on rare tree species at Kauhako Crater.

Rodents are not native to Guam or Saipan, and their impacts on the vegetation resources of AMME and WAPA are currently unknown. It is likely that rats are negatively impacting large-fruited tree species where they are present within the park. American Samoa also has alien rat populations, but there have been no studies to date on the impacts of rats on native plants of NPSA. However, data from native tree monitoring established within the Tutuila unit by Whistler (1994) and Heggie and Cairns (2001) may possibly contribute to a program to monitor rat impacts on native tree species, as both projects collected stand structure data. Those tree species with large seeds are most at risk from introduced rodents.

FIRE EFFECTS MONITORING

Most of the fire effects monitoring in the network has taken place at HAVO. Fire frequency is high at HAVO because of the prevalence of available fuels, high visitation, and lava flow ignition sources. Fire effects monitoring has been established largely in coastal lowland shrublands/grasslands and in the dry ohia woodlands. The results of these monitoring efforts from the 1980s have been summarized in PCSU Technical Reports (Tunison *et al*. 1994b, 1995b). In 2002-03, monitoring was established prior to prescribed burning for native plant restoration in both of these communities. Monitoring has also been established in uluhe (*Dicranopteris linearis*)-dominated rain forest, and montane seasonal koa forest and native shrublands, from the mid-1980s to 2003. Additional monitoring was established in mesic ohia forest and uluhe rain forest in 2003. The focus of the monitoring effort at HAVO has been plant population and community changes over time following wildfire or prescribed burning. Changes in the status of soil nitrogen have been evaluated in several burns on a one-time basis, and soil nutrients may be amenable to long-term monitoring. HALE has had only one fire in the last several decades, in 1993; that small burn is being monitored for vegetation changes. Monitoring transects were established in PUHE in 1990 and portions of those areas may have burned in large regional grass fires that have encroached on the park. Localized debris burns of dead, piled kiawe have taken place in the last decade, but no monitoring has been done. Small, prescribed burns are being monitored at PUHE in an effort to understand the relationship of exotic and native grasses and establish native pili grass . A small, prescribed burn was conducted adjacent to the parking lot at PUHO Visitor Center for similar purposes. Fires at KAHO have been limited to debris burning to remove kiawe; no monitoring has been associated with this operation. WAPA has a relatively high frequency of fire. Most fires are intentional, and result from agricultural practices or vegetation burning to facilitate pig and deer hunting. Arson also occurs. Natural wildfire is rare, and native vegetation is not adapted to a high fire frequency. A research project has been recently initiated by WAPA staff and the University if Guam to study fire and erosion in savanna vegetation. This monitoring program addresses some of the effects of land erosion on coral reefs, and it is paired with a program to monitor marine sedimentation. No fires have occurred at KALA, NPSA, or AMME.

Restoration and Re-introduction of Native Plants

HAVO has begun restoration or rehabilitation of fire-damaged communities in the coastal lowlands, dry ohia woodlands, and mesic ohia forest using out-plantings and seed sowing. Experimental vegetation rehabilitation is underway in dry ohia woodland damaged by alien insects, as well as in disturbed montane koa forest and soapberry savanna altered by years of cattle grazing. Out-plantings are monitored for survivorship, and direct seeding sites are monitored for germination, growth, and reproduction. In addition, rehabilitation sites are monitored on a community scale for diversity, cover, and density of plant species. Rare plant species are being re-introduced or augmented as part of a rare plant stabilization project in the subalpine, montane mesic forest, montane rain forest, lowland dry forest, and coastal strand. Rare plant restoration projects are monitored for mortality, growth, and reproduction on an annual basis. A large-scale, multi-year project to introduce the Mauna Loa or Kau silversword to HAVO involves annual monitoring of mortality and growth for a subset of more than 8,000 out-planted individuals and a goal of 12,500 plants (Tunison 2003).

HALE began restoring dry forests and shrublands in East Kaupo in 1995 by eliminating the mat-forming kikuyu grass (*Pennisetum clandestinum*) and outplanting seedlings of both common and rare species; this restoration effort is ongoing. Outplanting has been initiated in the central part of Haleakala Crater, and expansion of this program is planned. A program to stabilize and augment rare plant populations within the park was begun in 2000, and many endangered and rare species have been propagated and outplanted. This long-term project will involve a monitoring component. Previous survey and inventory work on the south slope of Haleakala (Medeiros *et al*. 1986), as well as studies of montane bogs (Loope *et al* 1991; Medeiros *et al*. 1991) and Kipahulu Valley rain forest (Lamoureux in Warner 1967; Anderson *et al*. unpublished; Medeiros *et al*. unpublished) will be invaluable for determining rare species re-introduction goals. The recent HALE flowering plant checklist (Medeiros *et al*. 1998) contains much information on rare plant collections and distributions within the park.

KALA has a native plant restoration project ongoing for coastal loulu lelo forest (G. Hughes pers. comm.), and exclosures have been placed in coastal strand communities for restoration and monitoring purposes. Inventory and monitoring of offshore islets have provided information on native species composition that may be used in future coastal restoration projects (Wood and LeGrande 2002). Recommendations of species deserving of re-introduction or augmentation have been made for Kauhako Crater (Medeiros *et al*. 1996), a dry to mesic forest recently fenced in preparation for a restoration effort. Feral ungulates are being removed from a section of the Puu Alii plateau, and some restoration efforts may be required for this rain forest.

PUHO and PUHE have introduced native plants to developed areas near buildings, but these landscape out-plantings have not been monitored. As part of future landscape restoration projects, both parks may re-introduce native plant species likely to have occurred in leeward coastal habitats. KAHO has begun a program of re-introducing native dryland coastal plant species, including a candidate endangered kookoolau. This restoration project includes augmentation of uncommon species from plant stock within the park, as well as introduction of species no longer found in KAHO but recommended for re-introduction by the Vegetation Management Plan (Pratt 1998). Additional native plants known from the park or identified in the pollen record may be introduced to areas where alien plants are removed (Stan Bond pers.

comm.). Some pollen analysis has been done for Aimakapa Pond (Douglas and Hotchkiss 1998), and further pollen core research is planned to identify native plants formerly growing in or near the park. Work on pollen assemblages of the Hawaiian Islands may lead to increased knowledge of past natural vegetation prior to human disturbance.

AMME, WAPA, and NPSA have no current native plant re-introduction projects. Raulerson and Rinehart (1989) suggested the introduction of palo maria (*Calophyllum inophyllum*, called kamani in Hawaii) to the coast at AMME to stabilize the jetty and shoreline picnic areas. Native strand plants were proposed for use in landscaping near the Headquarters of WAPA, but a recent typhoon damaged the building, and it is no longer occupied. Re-introduction of native plants may be considered for eroded savanna following a planned research project on recovery of savanna communities after fire (Dwayne Minton pers. comm.). Several projects involving re-introduction of native strand plants and restoration of historic vegetation to coastal units of WAPA were proposed after Supertyphoon Paka, but none was funded (Anderson, unpublished 1999). At NPSA, a proposal was recently developed to restore native tree species to Alava Ridge, an area disturbed by past road-building and agriculture within the Tutuila unit (Monello, unpublished 2003b).

LONG-TERM VEGETATION MONITORING

Long-term monitoring is perhaps the most important type of monitoring project for the purpose of answering questions about the stability of ecosystems and the effects of management activities in the National Park. Such projects are also the least common and most expensive of monitoring programs. The importance of National Parks and other natural areas for environmental monitoring was described by Moir (1972). “The idea of natural areas as environmental monitoring systems stems from their use as controls or benchmarks. Ecosystems in their more or less natural state are measured for predictive purposes against similar ecosystems that have been altered by man.” The long-term monitoring data sets identified below are a sampling of known vegetation monitoring projects that might be continued or repeated to provide guidance to managers.

HAVO is the site of numerous past and current research and management projects involving vegetation monitoring. Many of these, particularly weed and rare plant monitoring in SEAs (Abbott and Pratt 1996; Pratt and Abbott 1997; Pratt, unpublished data) , could be useful to managers if they were continued in the future. Permanent transects and plots associated with research projects of the recent past could be monitored to answer questions about long-term change in wet and mesic forests; the Rare Plant and Invertebrate Project (RPIP) is notable for forty large vegetation plots in which stand structure, tree density, and ground cover were measured (Pratt and Foote, unpublished data.). Several exclosures built within the park to determine impacts of alien ungulates have been in place for several decades, and these structures and associated data sets are extremely valuable for detecting long-term trends (Loope and Scowcroft 1985). One vegetation research project begun 25 years ago, the ohia rain forest or dieback study (Mueller-Dombois 1974, 1977; Mueller-Dombois *et al*. 1980), has six vegetation plots sited within the Olaa Forest and several others in forests of Kilauea. These HAVO vegetation plots have been re-monitored several times (Jacobi *et al*. 1984, 1988), and have been recently relocated and retagged as part of a new analysis of changes in vegetation over time (Boehmer, in prep.). Some of the permanent ohia dieback plots were also used to study nutrient limitations (Gerrish *et al.* 1988) and growth of ohia (Gerrish and Mueller-Dombois 1999). Vegetation data collected along elevational transects during the International Biological Program (Mueller-Dombois *et al.* 1981) may also be valuable for long-term studies of the vegetation of HAVO. The great variation in substrate ages and the continuing activity of volcanoes in HAVO provide a framework for monitoring vegetation in a successional context. At least one earlier study established permanent transects for studying succession in HAVO (Smathers and Mueller-Dombois 1974).

Long-term monitoring has not been established in all the vegetation types of HAVO; such a program would enhance the park's ability to detect change in vegetation over time. The subject of plant diseases and their impacts on native vegetation is one that deserves a monitoring project. The geographical extent, severity, and long-term implications of koa wilt disease (Anderson *et al*. 2001) and aalii yellows disease remain little understood in HAVO.

Sites within HAVO have been used for more than a decade to study nutrient cycling in montane rain forests, and data from the geologically young park sites (particularly near Thurston Lava Tube) have been compared with that of older sites on Hawaii and other islands as part of research along a substrate age gradient (Crews *et al*. 1995; Riley and Vitousek 1995; Hobbie and Vitousek 2000). Recently, nitrogen fixation in bryophytes, lichens, and wood was studied at park sites in Olaa and Thurston forests and compared with older sites in the soil-age gradient (Matzek and Vitousek 2003). Nutrient limitation during primary succession was studied at a site near Devastation Trail in HAVO (Vitousek *et al*. 1993).

HALE has long-term data sets for the Haleakala silversword in the Crater District. Other vegetation plots established on Puu Mamane, Halemauu Pali, Kalapawili grasslands, and West Kaupo may also be baseline data sets for future monitoring (Loope and Medeiros, unpublished). Monitoring of naenae (*Dubautia menziesii*) in the Crater and protected sandalwood on the West Slope will be useful to increase knowledge of rare and uncommon plants in the park. Detecting change in dry shrublands inside and outside 10-20 year old exclosures on the West Slope may be important for long-term studies. Vegetation recovery and degradation in bogs of the park were monitored for much of the 1980s (Loope *et al*. 1991; Medeiros *et al*. 1991), and these sites were recently re-visited by Hotchkiss and Werner (in prep.). This new effort to continue montane bog monitoring creates a long-term data set for this rare vegetation type. In Kipahulu Valley, there are permanent transects with weed data, rare plant data, and vegetation plots in which cover and density were measured (Anderson *et al*. 1992; Medeiros unpublished). Hotchkiss (in prep.) has recently re-sampled vegetation near the treeline of Haleakala, thus building on previous vegetation monitoring efforts and creating a long-term data set for the area; climate data is also being collected along an elevational gradient at HALE. A number of exclosures have been constructed in and near HALE over the last several decades (Loope and Scowcroft 1985), and these should be part of any long-term monitoring program. One transect established by Kitayama and Mueller-Dombois (1992) passed through the upper reaches of HALE and a large number of releves were used to sample vegetation in three elevational zones. These data on composition and structure of plant communities of the montane and high-altitude zones of windward Haleakala may provide a useful baseline for vegetation monitoring in the park.

Both HAVO and HALE were part of the study area for the Forest Bird Survey (Scott *et al.* 1986), and as part of the vegetation mapping component of this extensive, multi-island project, data on vegetation composition and cover were collected in plots every 150 m on transects at 2-mile intervals (Jacobi 1989, 1990). Transects have been relocated and flagged for subsequent bird surveys and vegetation plots at stations might be re-sampled as part of a long-term monitoring of park rain forests. The upper elevation forests of KALA were also part of the Forest Bird Survey study area. The three West Hawaii Historical Parks were inventoried for plants, birds and invertebrates in the 1990s. Baseline data on alien and native plant distributions and estimated abundance from systematic transects in PUHO and KAHO could be the basis for a long-term monitoring project (Pratt and Abbott 1996a, 1996b), or more repeatable methods and permanently marked vegetation plots could be designed for this purpose. PUHE was not sampled systematically in the 1990s (Pratt and Abbott 1996c), but Macneil and Hemmes (1977) sampled roadside vegetation with quadrats on short transects, and these might be relocated or replicated for a long-term (>25 years) monitoring program. Recent research projects on fountain grass at KAHO (Williams *et al.* 1995) and pili grass at PUHE (Daehler, unpublished) may provide baseline information for long-term studies of alien and native grasses.

WAPA has no current long-term vegetation monitoring ongoing, but future studies within savanna vegetation may provide data for such monitoring. The recent inventory of vascular plants in the seven units of WAPA (Yoshioka, in prep.) provides a baseline upon which monitoring may be designed. AMME has been monitored with four wetland transects (Raulerson and Rinehart 1989) that could be relocated and used for long-term studies. A recent wetland survey and plant inventory may provide information on recent changes in the vegetation of the park (Raulerson and Witteman, in prep.).

Vegetation of two NPSA units was studied by Whistler (1992, 1994), and his vegetation plots may be the basis for long-term monitoring of tree species. These plots are primarily in the Tutuila unit, and one was placed on Tau. Some of the vegetation plots were re-monitored by Travis Heggie (Stassia Samuels, pers. comm.). Recently, Heggie and Cairns (2001) placed 85 vegetation plots within the National Park unit on Tutuila, as part of a larger classification of forest types on the island. Ofu has received only a plant species inventory (Whistler 1992), and the newly-designated Olosega unit has not been recently surveyed. The Department of Marine and Wildlife Resources (DMWR) of American Samoa has a tree phenology project that uses sites within the park. This ongoing monitoring of trees used by fruit bats may constitute a valuable long-term vegetation data set that also relates to human exploitation of the park’s natural resources. One recent study investigated the nutritional quality of leaves and fruit consumed by fruit bats or flying foxes (*Pteropus samoensis* and *P. tonganus*) of Tutuila (Nelson *et al*. 2000).

FRAGMENTATION AND ADJACENT LAND USE

All the parks of the Pacific Network with vegetation resources exhibit some fragmentation of natural vegetation. HAVO and KAHO incorporate vegetation naturally fragmented by lava flows. Within HAVO there are large numbers of kipuka of all ages, “islands” of forest surrounded by recent lava flows. These natural forest fragments contribute to vegetation diversity and provide seed sources for developing vegetation on young substrates. Past land use within HAVO has also led to fragmentation. Prehistoric burning and historic wildfires have left some less flammable pockets of vegetation surrounded by alien plants. Past ranching in a park inholding (Ainahou) has also contributed to fragmentation. Current use as ranches of lands on either side of the Mauna Loa Strip separates the recovering koa forest from similar habitat on both the east and west. The disjunct Olaa Tract is bordered on two sides by farming and grazing land, which partially fragments this large (ca 3,700 ha) block of montane rain forest and separates it from rain forest of the Kilauea summit. HALE is similarly bounded by ranchland and areas infested with feral goats, as well as axis deer. Kipahulu Valley of HALE is less fragmented, because its upper reaches are bounded by a managed Natural Area Reserve and a TNC Preserve. However, little natural vegetation remains in lower Kipahulu, where native forest fragments are surrounded by a dense cover of alien plant species.

The three relatively small Historical Parks of West Hawaii all have highly disturbed lowlands, ranches, or urban areas adjacent on three sides. The situation at PUHE is particularly egregious, as construction of the adjacent Kawaihae Harbor involved dredging the sea floor and completely transformed the natural seacoast of the area. KAHO, PUHO, and PUHE may be considered terrestrial islands managed for natural values surrounded by highly modified lands. The peninsula upon which KALA is located naturally isolates the park, but some lands on the upper park boundary continue to be used as a cattle ranch. Because much of the KALA peninsula has been disturbed in the past, the natural vegetation of the lower part of the park is composed of relict forests or native strand vegetation surrounded by alien plant cover. Only the higher-elevation portion of KALA supports an expanse of rain forest, which is bounded by TNC Preserves.

AMME is a small park that contains a fragment of native vegetation, as well as alien plant cover and developed areas. It has an urban interface on two sides. The units of WAPA are all small areas, surrounded by highly modified areas, former military structures, current military reserves, and portions of villages. NPSA Tutuila unit exists in close proximity to the city of Pago Pago and the villages of Vatia, Fagasa, and Afono, but the three other units of the park are on islands with little urban development. The use of adjacent lands for subsistence farming and potential encroachment of cultivation onto parklands are serious concerns at NPSA.

Monitoring of adjacent land use and changes in use would be very helpful to planners at all Pacific Network Parks. Research into the optimal size of natural protected areas might identify appropriate areas to intensively manage in parks without current vegetation management and help refine the size and number of SEAs in the larger two parks. The question of the value of few large reserves versus many small ones has been addressed for animal populations in mainland parks (White 1986), but still has not been satisfactorily resolved (Shafer 1990; Swartz 1999).

WIDELY USED MONITORING METHODS

Many standard monitoring techniques have been used to measure vegetation in HAVO, HALE, and the other parks of the Pacific Network. Some past projects have used techniques of cover/abundance estimates to monitor vegetation, but these are most useful for vegetation classification and mapping (Mueller-Dombois and Ellenberg 1974). Frequency of occurrence data collected along transects is often used to describe the distribution of alien plant species within parks. Most recent monitoring projects have measured plant cover and density in randomly or systematically selected plots of different sizes. Rare plant distributions and abundance have been determined along belt transects. More recently Global Positioning Devices have been used for rare plant mapping. Rare plant population monitoring usually requires the marking, measurement, and periodic visitation of individual plants of the population. These methods and others are described in recent manuals of measuring and monitoring techniques for plant populations (Elzinga *et al*. 1998, 2001). Jacobi (2002) summarized different types of data commonly collected in natural resources monitoring programs, including presence/absence, population counts, frequency of plots, percentage of individuals by category, plant density, plant cover, and size measurements of individual plants.

Over the last two decades there have been attempts to standardize monitoring to make data more comparable among land management agencies in Hawaii. A notable attempt was initiated by The Nature Conservancy of Hawaii (TNCH); monitoring methods were developed to assess the biological resources and threats (such as feral animals) for TNCH Preserves and the State's Natural Area Reserves (Dunn 1992; Hawaii Heritage Program 1987). The TNCH Preserves and Watershed Partnerships in which TNCH participate all have monitoring plans and data sets from monitoring of vegetation, rare plants, weeds, and feral ungulates (C. Cory, pers. comm. 2002).

More recently monitoring plans have been developed for specific conservation areas to ensure adequate recovery of endangered plants. An example is the Makua Implementation Plan that is being developed for the Makua Military Reservation of the island of Oahu (in prep.). This plan specifies monitoring protocols for composition and structure of vegetation, evaluation of alien plant control, assessment of native plant populations, determination of success of out-plantings of rare native species, and detection of phytosanitation breaches. Methods are also prescribed for surveys of rare plants and invasive plants. Monitoring is an element of all community restoration projects in HAVO and HAVO, and monitoring plans are presented as part of each project review. Other network parks will incorporate monitoring into their rare plant and community restoration project proposals and work plans.

Elzinga *et al*. (1998) stressed that management objectives should be clearly defined prior to the development of a monitoring program. Sampling objectives, including details of statistical tests to be used to determine change and level of statistical significance required, must also be addressed prior to monitoring. The sampling design and selection of data analysis methods are the most important steps in developing a monitoring program (Jacobi 2002).

The monitoring plans developed by other NPS networks should provide useful information for the Pacific Islands Network monitoring plan. Many issues of sampling techniques and statistical analyses are shared by most parks and are not specific to one natural area or set of resources. Nonetheless, the monitoring plan for vegetation of the Hawaiian and Pacific Islands must take into consideration the highly endemic flora of the islands and the existence of vegetation types, such as tropical rain forests, which are not representative of vegetation of mainland North America. The volcanic nature of most of the Pacific Islands Network Parks, the natural isolation of the islands, and the vulnerability of island ecosystems to alien plant and animals invasions are all characteristics that somewhat distinguish the parks of the network from those of the American mainland.

Summary

CRITICAL RESOURCES

General

Intact or native-dominated plant communities that are not protected outside the National Parks; threatened and endangered plant species.

AMME

A wetland containing both native and non-native plant species is the most significant vegetation resource of this small park. The wetland containing mangroves is a type rare in the Northern Marianas and provides habitat for the endangered Marianas subspecies of Moorhenor gallinule (*Gallinula chloropus guami*) and the endangered Nightingale Reed Warbler (*Acrocephalus luscinia*). The humped tree snail (*Partula gibba*), a species of conccern, also occurs within the park.

WAPA

Limestone forest remnants, savanna vegetation recovering from fire, and riverine forests are significant vegetation resources. The Asan Inland and Asan Beach units comprise an entire sub-watershed and may provide significant opportunities for ecological research. Although more than half the documented terrestrial plant species are alien, the recent inventory identified significant areas of largely native vegetation within several park units (Yoshioka, in prep.).

NPSA

Montane rain forest and summit scrub is most vulnerable on Tutuila, and the lowland maota mamala rain forest is a critical resource of Tau. All native vegetation types in the park are important, as they are unique among NPS units. Rare plant species need to be identified and protected; none are currently listed as endangered. Native fruit-bearing tree species are important as food sources for rare fruit bats and uncommon many-colored fruit-doves (*Ptilinopus perousii*). Plants of ethnobotanical importance are also potential monitoring subjects.

USAR

There are no significant native vegetation resources, although a few native plants have been used to landscape the visitor center.

KALA

The upper-elevation rain forests of Waikolu and Puu Alii, diverse dry forest in Kauhako Crater, coastal strand communities, coastal forest, and unusual relict vegetation on offshore islets are important resources. There are several threatened and endangered species and species of concern found on the Kalaupapa Peninsula and offshore islets. The endangered awiwi occurs within an exclosure and the threatened *Tetramolopium rockii* var. *rockii* is a component of one of the strand communities. Additional T & E plant species may be found on unsurveyed cliffs in or near the park. The rain forests of Puu Alii NAR support many threatened, endangered, and rare plant species.

HALE

Recovering alpine aeolian cinderland, subalpine grassland and shrubland, montane bogs, cloud forest, rain forest, mesic and dry shrublands and forests are notable for high native species diversity. The protected rain forests of Kipahulu Valley, a research natural area and scientific reserve, are particularly important. Subalpine lakes and riparian habitat of perennial streams are valuable resources. The park supports at least 15 threatened and endangered plant species, 11 candidate endangered species, approximately 22 species of concern and almost 30 rare plant species; additional species within these categories are thought to have been extirpated from HALE.

PUHE

Native plant resources are concentrated in the strand and small wetland community. Experimental areas in which pili grass is being restored are important to future restoration efforts. A population of the rare pololei fern persists in the park.

KAHO

The wetlands surrounding the two large fishponds are significant examples of much-depleted plant communities. Coastal strand and areas around anchialine pools also contain many native plant species. The park supports a large population of pua pilo, a species of concern, and smaller numbers of a candidate endangered species and a second SOC.

PUHO

Coastal strand and marshes surrounding anchialine pools support largely native vegetation. Other native plants are found scattered in alien-dominated vegetation. One species of concern and several uncommon lowland plant species are known from the park. Endangered loulu palms have been planted near the Visitor Center. The detached upland garden has out-plantings of several endangered plant species native to Hawaii Island.

HAVO

Diverse mesic forests and rain forests of both Mauna Loa and Kilauea East Rift; upper montane, subalpine and alpine communities; relictual dry forests; lowland ecosystems proposed for restoration; beach and strand communities, anchialine ponds; and early successional lava flows and kipuka are significant vegetation resources. There are 22 threatened and endangered plant species, 5 candidates for endangered status, 22 species of concern, and 40 rare plant species known from the park; this includes several extirpated and extinct species. The native plant resources of the Kahuku addition have not yet been evaluated. Native plant species and communities are of cultural significance in the context of traditional gathering.

ALKA

The vegetation resources of the newly designated Ala Kahakai Trail have not been inventoried.

Table 1. Critical Resources of the PACN Parks (excluding ALKA and USAR)

	AMME	WAPA	NPSA	KALA	HALE	PUHE	KAHO	PUHO	HAVO
Native Vegetation	X	X	X	X	X		X	X	X
Wetlands/Riparian Veg	X	X	X	X	X	X	X	X	X
Entire Watershed		X	X	X	X				
Limestone Forest		X							
Alpine incl. Cinderland					X				X
Subalpine Grass/Shrubland					X				X
Montane Bogs					X				
Montane Rainforest			X	X	X				X
Lowland Rainforest			X	X	X				X
Diverse Dry/ Mesic Forest incl. limestone		X		X	X				X
Coastal Strand	X	X	X	X	X	X	X	X	X
Offshore Islets		X	X	X					
Successional Lava Flows									X
Rare Plant Spp.		X	X	X	X	X	X	X	X
Endangered Plant Spp.				X	X			X	X
Ethnobotanic Spp.			X	X	X	X, pl		X, pl.	X

STRESSORS ON VEGETATION AND FLORA

General/common stressors

Alien species invasions; visitor impacts in sensitive areas; effects of nearby development; contamination; type of management in surrounding areas parks including introduction of new species; loss of key ecosystem components; loss of biodiversity (listed by many parks but really a result, not a cause); and potential losses due to natural causes such as lava flows or climate change.

AMME

Visitor impacts in sensitive areas, including past turf removal and dumping in the wetland; encroaching development from the adjacent town; newly invasive plants. Alien vines, such as ivy gourd and chain-of-love (*Antigonon leptopus*), have recently appeared in the park and are invading the edge of the wetland.

WAPA

Wildfire and subsequent erosion, particularly in savanna vegetation; adjacent incompatible development; invasive ungulates (feral pigs, Philippine deer) and alien plants; typhoons that repeatedly disturb vegetation cover, particularly in limestone forest.

NPSA

Expanding subsistence agriculture into forest; invasive alien plants and animals (feral pigs, rats, ants, etc.); diseases. Potential stressors are new invasive alien species, climate change, hurricanes, incompatible tourism-related development on adjacent lands, and human population growth that leads to loss of habitat for native species.

USAR

There are no significant terrestrial vegetation resources associated with this park.

KALA

Human impacts on offshore islands; invasive alien plants and animals (ungulates, rats, mosquitoes, ants); diseases; loss of biodiversity. Potential stressors are altered disturbance and succession regimes and new invasive alien plants and animals.

HALE

Alien plants and animals (feral pig, feral goat, axis deer, rats, ants, mosquitoes, trespass cattle); diseases; potential new introductions; visitor impacts in alpine zone; loss of key species (insect hosts, plant dispersers and pollinators); and potential wildfires.

PUHE

Invasive alien plant species, particularly kiawe, puncture vine , fountain grass, other alien woody plants that may damage cultural resources, and pickleweed recently removed from the coastal wetland; fire; erosion; in-park development. Potential stressors are development of a liquid-fuel storage facility adjacent to the park; resource damage from fuel spills and increased visitation from adjacent Kawaihae Harbor; damage from dirt bikes using the coral flats and stream bank.

KAHO

Development of coastal lands near the park; alien vegetation; erosion of sandy shoreline; invasive alien ungulates, rats, and ants; loss of biodiversity; and visitor impacts to natural resources. Potential stressors are the rise of sea level due to global warming, expansion of the adjacent Honokohau Harbor, additional development of mauka lands, increased visitation, and invasion of new alien plants and animals.

PUHO

Erosion of coastal areas, particularly with rising sea level due to global warming; incompatible development encroaching on park; invasive alien plants, including those already established (koa haole and *Pithecellobium dulce*) and encroaching invaders not yet well established in the park (ivy gourd); and visitor impacts to natural resources.

HAVO

Feral ungulates; invasive alien plants; rats; yellowjacket wasps ; mosquitoes; ants; diseases; loss of pollinators; small population size of native organisms and loss of endemic plant and animal species; change in nutrient, soil water, and fire regimes; wildfire; lava flows and volcanic emissions; incompatible uses in adjacent lands; park development; visitor impacts.

ALKA

Stressors are unknown at this time; surveys and evaluation of vegetation resources are necessary.

Table 2. Stressors of the PACN Parks (excluding ALKA and USAR)

	AMME	WAPA	NPSA	KALA	HALE	PUHE	KAHO	PUHO	HAVO
Invasive Alien Plants	X	X	X	X	X	X	X	X	X
Rats/Feral Ungulates		X	X	X	X		X		X
New Invaders	X		X	X	X		X	X	X
Visitor Impacts	X			X	X	X	X		X

	AMME	WAPA	NPSA	KALA	HALE	PUHE	KAHO	PUHO	HAVO
Nearby Development	X	X	X			X	X	X	X
Loss of Key Ecosys. Comp.					X				X
Loss of Biodiversity				X			X		X
Wildfire/Erosion		X		X	X	X	X	X	X
Typhoons	X	X	X						
Climate Change/ Sea Level Rise	X	X	X	X	X	X	X	X	X
Diseases			X	X	X				X
Alien Invertebrates		X		X	X		X		X
Expanding Subsistence Ag.			X						
Altered Succession/ Nutrients/Water	X				X				X
Lava Flows/Emissions									X

MONITORING NEEDS

AMME

Wetland community monitoring (baseline monitoring was accomplished in FY02); vegetation/habitat requirements of rare wetland bird species; status of wetland intertebrates; impacts of invaisve plant species.

WAPA

Fire effects and erosion in savanna vegetation; impacts of feral ungulates and alien plant species; changes in limestone forest composition and cover. Completion of inventory work is a prerequisite for extensive monitoring.

NPSA

Rain forest ecosystem health; expansion of subsistence farming and effects of human disturbance; ungulate impacts on native vegetation; alien plant distribution monitoring; effectiveness of weed treatment and ungulate removal; population trends of rare plants (once they are identified).

USAR

No vegetation monitoring needs are known for this park.

KALA

Rain forest, dry forest, and strand community recovery after feral deer and pig removal; rare plant population monitoring; vegetation mapping at a scale that shows native vegetation fragments and patch size; rain forest boundary mapping.

HALE

Rare plant population monitoring; alien plant distribution monitoring, including incipient invaders; continued treatment effectiveness monitoring in areas receiving alien plant control, feral ungulate removal, and restoration of native vegetation; recovery of significant plant communities; long-term changes in rain forests, diverse mesic forests, and upper montane, subalpine, and alpine ecosystems.

PUHE

Treatment effectiveness monitoring of areas converted from alien vegetation to pili grassland; monitoring of population of the rare pololei fern; monitoring of re-introduced native plants and restored communities.

KAHO

Wetland community monitoring; monitoring of both native and alien plants invading anchialine pools and causing senescence and infilling; native tree and shrub population monitoring; effectiveness of native plant introduction or re-introduction in alien plant removal areas; alien plant treatment effectiveness monitoring; rare plant population monitoring.

PUHO

Population monitoring of selected native and Polynesian plant species; community-level monitoring of coastal strand and wetland vegetation; effects of alien plant treatment and native plant re-introduction efforts (out-planting).

HAVO

Rare plant population monitoring; alien plant distribution monitoring, including incipient invaders; continued treatment effectiveness monitoring in areas receiving alien plant control, feral ungulate removal, and restoration of native vegetation; recovery of significant plant communities; impacts of cultural collecting on the population or community level; effects of fire; long-term changes in rain forests, diverse mesic forests, and upper montane, subalpine and alpine ecosystems; early succession on lava flows and kipuka complexes.

ALKA

Monitoring needs are currently unknown.

Table 3. Monitoring Needs of the PACN Parks (excluding ALKA and USAR)

	AMME	WAPA	NPSA	KALA	HALE	PUHE	KAHO	PUHO	HAVO
Wetlands	X			X			X	X	X
Habitat Req. of Rare Spp.	X								
Impacts/Feral Ungulates		X	X	X					
Impacts/Dist. Alien Plant Spp.		X	X		X		X		X
Vegetation Change/Recovery (incl.strand)		X	X	X	X		X	X	X
Fire Effects/Erosion		X		X					X
Vegetation Restoration				X	X	X	X	X	X
Rainforest Health/Recovery			X	X	X				X
Long-term Change Montane/Subalpine/Alpine					X				X
Weed Treatment Effectivenes			X	X	X	X	X	X	X
Ungulate Removal Effectiveness			X	X	X				X
Trends in Rare Plant Pops.			X	X	X	X	X	X	X
Human Disturbance			X						
Expansion of Farming			X						
Veg mapping/Fragments				X					
Impacts of Cultural Collecting									X
Succession on Lava/Kipukas									X

Research Needs

In general, protocols are in place for monitoring rare plant populations, alien plants, recovery after feral animals and fires, and vegetation community monitoring. Many past and current monitoring projects exist for HAVO and HALE, and to a lesser extent in the Kona Historical Parks. Little monitoring or vegetation research has been carried out in the parks of the Western and South Pacific. Research may be needed to develop statistically valid monitoring protocols applicable to a wide range of plant communities, populations, environments, and sampling questions. These may involve pilot studies to determine proper sample size and monitoring design. Past sampling methods and design varied greatly. Many environments have not been adequately sampled; vegetation of some parks and park units has not been systematically sampled at all. Monitoring methods in the past were developed piece-meal to answer specific monitoring questions. Pilot studies were rarely conducted.

Research to identify indicator species may be needed to develop efficient monitoring programs in many environments of the parks. Rare plant limiting factors research may help refine monitoring programs focused on rare plant populations, particularly in the large parks, which contain numerous rare and sensitive plant species. Weed species biology is largely unknown, even for species being controlled in large segments of the parks. More research into weed species life histories, phenology, seed production, seed dispersal, seed banks, and limiting factors in their native ranges would provide data useful for refinement of alien plant control and containment strategies in the network parks. Priority should be given to research on alien plant species that are current or potential threats to more than one park unit and to studies of native species and communities at risk of being lost from parks.

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